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TRANSACTIONS

OF THE

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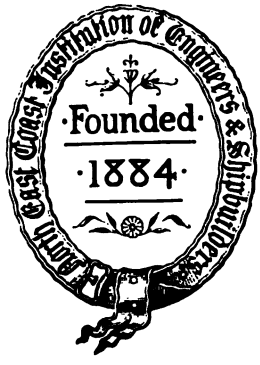
OF

ENGINEERS AND SHIPBUILDERS.



VOLUME I.

SESSION 1884-5.

Newcastle-upon-Tyne:
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1885.

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ADVERTISEMENT.

"The Institution merely places on record, and is not, as a body, responsible for the statements or opinions advanced in the Papers read, or the Discussions thereon, which occur at the Meetings during the Session."

THE NORTH-EAST COAST INSTITUTION

OF

ENGINEERS AND SHIPBUILDERS.

Constitution and Bye-Laws,

ADOPTED AT A GENERAL MEETING ON THE 4TH MARCH, 1885.

CONSTITUTION.

I.—The NAME of the Association is "The North-East Coast Institution of Engineers and Shipbuilders."

II.—The OBJECTS for which the Institution is established are:—The advancement of the science and practice of Engineering and Shipbuilding, and the interchange of ideas and information amongst its members, by means of meetings for the reading and discussion of papers relating thereto, and placing on record its transactions.

III.—The Institution shall consist of Honorary Members, Members, Associates, and Graduates.

IV.—HONORARY MEMBERS shall be such distinguished persons as the Council may elect.

V.—MEMBERS shall be Principals or Principal Managers engaged in Engineering or Shipbuilding; Civil, Military, or Mining Engineers, or Naval Architects; whose subscription shall be Two Guineas per annum; and other persons engaged in the above professions; whose subscription shall be Half-a-Guinea per annum.

VI.—ASSOCIATES shall be such persons as are not strictly Engineers or Shipbuilders, but are connected with or interested in such pursuits, and are deemed by the Council to be eligible for Associate membership. Their subscription shall be One Guinea per annum.

VII.—GRADUATES shall be persons under twenty-one years of age, engaged in study or employment to qualify themselves for any of the above professions. Their subscription shall be Five Shillings per annum.

VIII.—Any MEMBER may become a LIFE MEMBER by a single payment of twenty guineas, or any ASSOCIATE may become a LIFE ASSOCIATE by a single payment of ten guineas.

IX.—The OFFICERS of the Institution shall be elected from and by the Members, and shall consist of one President, the Past-Presidents, six Vice-Presidents, fifteen Councilmen, and a Treasurer.

X.—The President and Treasurer shall be elected annually. Two Vice-Presidents and five Councilmen shall be elected annually. The retiring Vice-Presidents and Councilmen shall, at the end of the first year, be decided by ballot from the whole number; at the end of the second year, by ballot from the number who have served two years; and each succeeding year they shall be those who have served three years from their last election.

The President shall be eligible for re-election for a second year; should he be re-elected he shall retire at the conclusion of his second year of office, and shall not again be eligible until after an interval of one year.

The retiring Vice-Presidents and Councilmen shall not be eligible for re-election to the same offices until after a similar interval, but shall be eligible for election to any other office.

The Treasurer shall be eligible for re-election annually, or for election to any other office.

XI.—Honorary Members may attend all the General Meetings, they may read papers, take part in discussions, in voting, in moving and supporting resolutions, in presentation of notices of motion, or in requisitions for Special Meetings, and in the proposition of new members; they shall also receive copies of the Transactions.

XII.—Members shall have all the privileges of the Institution, as enumerated in the foregoing paragraph, and shall be eligible for office.

XIII.—Associates shall have all the privileges enumerated in paragraph XI. They shall not be eligible for office.

XIV.—Graduates may attend all the General Meetings, they may read papers, take part in discussions, and support resolutions; they shall also receive copies of the Transactions, but shall not sign proposals for new members, vote, nor be eligible for office.

XV.—The General Meetings of the Institution shall be held during the winter seasons of each year.

NOTE.—When the word Member is initialled with a capital letter it signifies a member under paragraphs IV. and V., but when initialled with a small letter, it signifies a member of any class of the Institution membership.

BYE-LAWS.

MEMBERSHIP.

1.—Every candidate for admission as a Member, Associate, or Graduate shall be proposed and recommended according to the Form A in the Appendix, in which form the name, usual residence or the place of business, the qualification for, and proposed class of membership of the candidate shall be distinctly specified.

The form shall be signed by a Member or Associate of the Institution, as proposer, and by at least other three Members or Associates as supporters, certifying a personal knowledge of the candidate.

The proposal so made shall be submitted to the Council, when, if it be approved, the Chairman shall sign the approbation, which shall be inserted in the notice calling the next General Meeting, when the candidate shall be balloted for, and shall be accepted if three-fourths of the votes are favourable.

2.—Graduates desirous of becoming Members shall be proposed and recommended according to the Form B in the Appendix.

The proposal so made shall be submitted to the Council, who shall agree to or reject it.

3.—The balloting for membership shall be conducted in the following manner:—Each Member shall be supplied by post with a list of the names of the candidates, according to the Form C in the Appendix, and shall strike out the names of such candidates as he desires shall not be elected. These lists may be returned to the Secretary by post, or may be deposited in the ballot-box by the voter in person on entering a meeting at which an election is to take place. The ballot-box will be closed at ten minutes after the advertised time of meeting. The lists shall then be handed over to the Chairman, who shall appoint two Scrutineers to examine them, after which examination the Chairman shall inform the meeting of the result.

4.—Notice of Election as a member shall be sent to the candidate within one week after his election, according to the Form D in the Appendix; but his name shall not be added to the list of Members, Associates, or Graduates of the Institution, until he shall have paid his first annual subscription.

5.—In case of rejection of the candidate, no mention thereof shall be made in the minutes, nor shall any notice be given to the unsuccessful candidate.

6.—All Subscriptions shall be payable in advance, and shall become due on the 1st of June each year. Application for membership may be made at any time during a Session, and the subscription shall cover the membership up to the 1st of June following.

7.—On receipt of each subscription, the Treasurer shall forward to the member an official receipt for the amount; and shall forward to the Secretary a card of membership for the current year, signed by the Treasurer, to be countersigned by the Secretary, and forwarded to the member. The Forms E, F, G, H, EE, and FF, in the Appendix, illustrate the cards of membership.

8.—On questions of privilege, any person who may be unknown in the meeting, shall only be able to claim the privilege in question on production of his card of membership for the current session.

9.—Any member whose subscription is two years in arrear, shall be reported to the Council, who shall direct application to be made for it, according to Form J in the Appendix; and in the event of its continuing one month in arrear after such application, the Council shall have the power, after remonstrance by letter, according to the Form K in the Appendix, of declaring that the defaulter has ceased to be a member.

10.—The Council may refuse to continue to receive the subscriptions of any member who shall have wittingly acted in contravention of the Regulations of the Institution, or who shall, in the opinion of the Council, have been guilty of such conduct as shall have rendered him unfit to continue his membership; and the Council may remove his name from the list of members: and such person shall thereupon cease to be a member of the Institution. Notice of such action of the Council shall be forwarded to the person in question, in accordance with the Form L in the Appendix. The reason for such action of the Council shall not be stated to the person expelled, without the sanction of the Council.

OFFICERS.

11.—The Annual Election of Officers shall be conducted in the following manner:—The Council shall meet in March or April, and shall arrange a list of nominations, in accordance with the Form M in

the Appendix. Such list shall be presented at the General Meeting immediately preceding the last General Meeting of the Session, and any Member present shall be at liberty to nominate additional Members. The list shall show who remain in office throughout the Council, and who are retiring. It shall nominate new names in the place of the retiring Members, and the number of nominations shall be, at least, two in excess of the number required in each section of the Council. A copy of this ballot list shall be forwarded to each Member and Associate, together with a complete list of Members, to be filled in, in accordance with the instructions printed in the ballot form, and to be returned to the Secretary, to be opened in the presence of the Council, at a Council Meeting which shall be held in April or May, when the scrutiny and counting shall be carried out by the Council. Any Member in voting shall be at liberty to erase any name or names from the list and substitute the names of any other person or persons eligible for each respective office other than those already placed on the ballot list by the Council and Members of the Institution.

Any voting paper returning either more or less than one President, six Vice-Presidents, one Treasurer, and fifteen Councilmen, shall be disqualified for the section or sections in which such errors occur, and the votes shall be lost for the said section or sections. The votes given as President, to a Member who is not elected President, shall count to him as a Vice-President; the votes given as Vice-President, or Treasurer, to persons not so elected, shall count to them as Councilmen, unless they have just completed a term of office in such capacity.

The voting list shall not be sent to any Member and Associate whose subscriptions are more than one year in arrear; nor shall any such Member be nominated on the list. For this purpose, the Treasurer shall prepare previously to the meeting of Council, a list of those Members whose subscriptions are more than one year in arrears.

12.—The result of the ballot for Officers shall be declared at the General Meeting, to be held in May, at which meeting general business shall be transacted. At the May General Meeting the newly-elected Officers, after being declared, shall enter into office; and this shall be the last meeting of the session.

13.—The Council shall have power to supply any casual vacancy within itself (including any casual vacancy in the office of President), which shall occur between one May Meeting and another;

and the officers so appointed shall retire when the person whose place they fill would have retired. Vacancies not filled up during the year shall be filled at the General Election.

GENERAL MEETINGS.

14.—The Annual General Meeting shall take place in October, and shall be held in Newcastle. The Ordinary Meetings shall take place in the second week of each following month during the session, at such hours and places as the Council may determine.

15.—Seven clear days' notice of every General Meeting, Ordinary or Special, specifying the nature of business to be transacted, shall be given to every member of the Institution.

16.—A Special General Meeting may be convened at any time by the Council, and such meeting shall be convened by the Council whenever such is the declared wish of a General Meeting, or whenever a written requisition signed by twenty members, specifying the object of the meeting, is left with the Secretary. If, for fourteen days after the delivery of such requisition, a meeting be not convened in accordance therewith, the requisitionists, or any twenty members of the Institution, may convene a Special Meeting in accordance with the requisition. The business discussed at such Special Meetings shall only be that indicated on the notice calling the meeting.

17.—Twenty Members shall consitute a quorum for the purpose of a meeting other than a Special Meeting. Thirty Members shall constitute a quorum for the purpose of a Special Meeting.

18.—The President shall be chairman at every meeting, or in his absence, one of the Vice-Presidents; or in the absence of all the Vice-Presidents, a Councilman shall take the chair ; or if no Councilman be present and willing to take the chair, the meeting shall elect a Chairman.

19.—The decision of a General Meeting shall be ascertained by a show of hands ; or, when five Members or Associates shall demand, or the Chairman may think it desirable, the decision shall be taken by a show of Members' and Associates' tickets. The manner of counting the show of hands or of tickets shall be at the discretion of the Chairman, and an entry in the minutes, signed by the Chairman, shall be deemed sufficient evidence of the decision of a General Meeting. In cases of equality of votes, the Chairman shall have a casting vote ; otherwise he shall not vote.

20.—Questions of a personal nature arising in a General Meeting, shall, if possible, be referred to the Council, otherwise the decision of the meeting shall be taken by ballot on a motion or amendment put to the meeting. The ballot shall be taken by the voters (being Members or Associates) writing "for" and "against" on a slip of paper. The slips shall be folded and collected, and then counted in the presence of the meeting, and the result announced by the Chairman. Should fewer than twenty votes be given, it shall be understood that the question is shelved, and the votes shall be destroyed without being opened.

21.—At every General Meeting of the Institution, the Secretary shall first read the minutes of the preceding meeting, which, on approval, shall be signed by the Chairman; business arising out of these minutes shall then be transacted. The Secretary shall read any notices which may have to be brought before the meeting. Notices of motion may then be given, and other business of the Institution may be attended to; but when a paper is to be read, the foregoing business shall not be extended beyond half-an-hour after the advertised time for commencing the meeting. The paper or papers for the evening shall then be read and discussed.

22.—If within half-an-hour after the time fixed for holding a General Meeting a quorum is not present, the meeting shall be dissolved, and all matters which might, if a quorum had been present, have been done at the meeting so dissolved, may forthwith be done on behalf of the meeting, by the Council; except the reading or discussion of a paper, which shall not proceed in the absence of a quorum.

23.—Any General Meeting of the Institution may be adjourned by a vote of the Members and Associates present if there be a quorum; if there be not a quorum, the case shall be met by the preceding paragraph.

24.—Each member shall have the privilege of introducing one friend to the General Meetings, for whom he must obtain, from the Secretary, a card of admission (see Form N in Appendix), but during such portions of any of these meetings as may be devoted to any business connected with the management of the Institution, visitors may be requested by the Chairman to withdraw. This shall be done if five Members or Associates, or both, present request it.

COUNCIL MEETINGS.

25.—The Council shall meet before each General Meeting, or on other occasions when the President shall deem it necessary; being summoned in either case by circular, stating the time of meeting, and the business, so far as is known.

No business involving expenditure of the funds of the Institution (except by way of payment of current accounts) shall be transacted at any Council Meeting, unless the circular gives six clear days' notice, and states the business.

All discussions of a personal character in the Council shall be considered and treated as being strictly confidential.

26.—The Council may regulate its own procedure, and delegate any of its powers and discretions to any one or more of its number.

The President shall, *ex-officio*, be chairman of all Council Meetings, and in his absence one of the Past-Presidents or one of the Vice-Presidents shall take the chair, or in the absence of these, one of the Councilmen shall be elected to take the chair. Five members of Council, including the Chairman, shall form a quorum.

In the appointment of Sub-Committees, the Council shall determine the number which shall form a quorum in each case, and shall appoint a Chairman.

27.—The Council may appoint Committees either from itself, or with the assistance of persons outside, for the purpose of transacting any special business, or of investigating specific objects connected with the work and interests of the Institution.

28.—All Committees or Sub-Committees shall be appointed by the Council, and shall be subject to that body, and shall report to it. The Council shall act upon these reports or recommendations as it may think best.

29.—The Council may invite to General Meetings or to Council Meetings any person or persons whose presence and assistance it may desire, and strangers so invited shall be permitted to take part in the proceedings, but not to vote.

30.—The Secretary and Treasurer shall act under the direction and control of the Council, by which body their duties shall, from time to time, be defined.

31.—The Secretary shall take minutes of the proceedings at all meetings of the Institution and Council, and enter them in proper books provided for the purpose. He shall write the correspondence of the Institution and Council, read minutes and notices at meetings, report discussions, perform whatever other duties are indicated in the Bye-Laws of the Institution as appertaining to his department, and, if required by the Council, prepare papers for reading and publication, and read papers and communications at the meetings. The Secretary shall be appointed by the Council, and paid such salary as the Council may decide; he shall attend all Meetings, Council or General, but shall not vote. He shall remain in office during the pleasure of the Council.

32.—The Treasurer shall receive all payments due to the Institution, and shall bank the cash in hand whenever it amounts to ten pounds. The bank shall be determined by the Council, and the banking account shall be in the names indicated in connection with the Finance Committee. The Treasurer shall keep a cash account book, general and detail, which shall on all occasions be open to inspection by the Finance Committee or by the Council. He shall keep a register of the names of members, so arranged as to distinguish all members whose subscriptions are in arrear. He shall also perform whatever other duties are indicated in the Bye-Laws of the Institution as appertaining to his department.

33.—A Finance Committee shall be appointed as a Sub-Committee of the Council, and shall consist of seven persons, viz., one Vice-President, who shall be Chairman; four Councilmen, the Secretary, and the Treasurer of the Institution.

The Treasurer shall be empowered to pay all amounts due from the Institution which are under two pounds. All amounts of two pounds and upwards shall be paid by cheque signed by the Chairman of the Finance Committee, the Secretary, and the Treasurer.

TRANSACTIONS.

34.—The notice calling a General Meeting, at which a paper is to be read, shall, when such can be arranged, contain a syllabus of the subject of the paper.

35.—All papers shall be submitted to the Council for approval, and on their general approval, shall be handed to a Reading Sub-Committee, at least three of whom shall read the paper through.

The Reading Committee shall be at liberty to strike out any parts which, in their opinion, ought not to be read. They may also make any suggestions to the author as to points which might with advantage be inserted or altered. The Secretary shall not be a member of this Committee.

36.—The papers read, and the discussions on them, or such portions of them as the Council shall select, shall be printed for distribution among the members, each of whom shall receive a copy. These Transactions shall be edited by the Secretary, in accordance with instructions of the Council, who shall have power to omit parts of discussion which may be foreign to the subject, or which it may be deemed undesirable to retain. Each paper shall bear the date on which it was read in General Meeting.

37.—A copy of the paper shall, when possible, be sent four days before the date of reading to any Member who shall have applied to the Secretary for it, in writing, fourteen days before the date of reading.

38.—Proofs of the reports of discussions shall be sent for correction to the members who have taken part in the discussion, but must be returned to the Secretary within seven days of the date on which they were sent, otherwise they will be deemed correct, and will be printed off.

39.—The Council shall be at liberty to print as Transactions, either with the papers and discussions or separately, explanatory notes, etc., communicated after the reading or discussing of a paper. Such communications shall bear the date on which they shall have been received by the Secretary.

40.—The Institution shall not be held responsible for the statements and opinions advanced in any of the papers which may be read, or in the discussions which may take place at the Meetings of the Institution.

41.—Twenty copies of each paper and discussion shall be presented to the author of the paper, for private use, and one copy shall be sent to each member. Duplicate copies of parts of the transactions mislaid or lost by members cannot be supplied to them, except as provided for in Bye Law 44.

42.—The Transactions shall not be supplied free to members whose subscriptions are more than one year in arrear.

43.—Any member elected at any time between the Annual General Meetings shall be entitled to copies of all the Transactions issued during the session to which his first subscription applies; but not until the subscription has been paid.

44.—The Transactions of the Institution shall be the exclusive property of the Institution, and shall be published only by the authority of the Council. They shall be sold only by the Secretary, in such manner and at such prices as the Council shall have fixed.

45.—During a discussion upon any paper, no person shall be at liberty to speak more than once (except by way of explanation), nor for a longer period than ten minutes.

ACCOUNTS.

46.—The Council shall present the yearly accounts (up to the 31st of May preceding) at the October General Meeting of each year, after they have been audited by a professional Accountant, appointed by the members at the General Meeting in May.

ALTERATIONS TO CONSTITUTION AND BYE-LAWS.

47.—Alteration in or addition to the Constitution and Bye-Laws may be made only by resolution of the members at the May General Meeting, after notice of the proposed alteration or addition has been announced at the previous General Meeting.

The resolution may be modified by the Council meanwhile, should they so desire; but in this case it shall be read at the May General Meeting in its original form before it is proposed in the amended form.

Such resolutions shall be stated in the notice calling the intervening Council Meeting, and also in the notice calling the May General Meeting.

Any member unable to be present at the meeting at which such alterations are to be considered, but who is nevertheless desirous of

recording his opinion thereon, shall be allowed to vote by proxy, such proxies shall be in Form O in the Appendix, which may be had on application to the Secretary, and may be used by any member present at the meeting on behalf of the absent member, and counted by the Chairman as of equal value with votes given in the manner provided in Bye Law 19.

APPENDIX.

FORM A. (BYE-LAW 1.)

A. B. [Christian Name, Surname, Occupation, and Address in full] being desirous of admission into the North-East Coast Institution of Engineers and Shipbuilders, we, the undersigned [Members or Associates], propose and recommend that he shall become [a Member, Associate, or Graduate] thereof. We know him to be [a Principal, &c., or engaged in, &c.,] and eligible for the proposed membership.

FROM PERSONAL KNOWLEDGE.

Signed _____

_____

_____

_____ } Four [Members or Associates].

Dated this day of 18

FORM B. (BYE-LAW 2.)

A. B. [Christian Name, Surname, Occupation, and Address in full] being at present a of the North-East Coast Institution of Engineers and Shipbuilders, and upwards of twenty-one years of age, and being desirous of becoming a of the said Institute, we, the undersigned [Members or Associates], recommend him, from *personal knowledge*, as a person eligible for the proposed Change of membership, because—

(*Here specify distinctly the Qualifications of the Candidate according to the spirit of the Rules of the Institution.*)

Signed _____

_____

_____ } Three [Members or Associates].

Dated this day of 18

FORM C. (BYE-LAW 3.)

BALLOTING PAPER FOR MEMBERSHIP.

The Council having considered the recommendations for Membership of the following gentlemen, present them to be balloted for, viz.:—

MEMBER.	ADDRESS.	ASSOCIATE.	ADDRESS.	GRADUATE.	ADDRESS.

Strike out the names of such persons as you desire shall *not* be elected, and forward the list by post to the Secretary, or personally place it in the ballot-box at the Meeting.

FORM D. (BYE-LAW 4.)

SIR,—I am directed to inform you that on the day of you were elected a of the North-East Coast Institution of Engineers and Shipbuilders, but, in conformity with Bye-Law 4, your election cannot be confirmed, nor your name be added to the roll of membership, until you have paid your first annual subscription, the amount of which is £ : : , or, at your option, the Life Composition of £ : : .

Payment may be made to the Treasurer, Mr._____

Address_____

I am, Sir,
Yours faithfully,

Secretary.

Dated 18

N.B.—In case of a Graduate, strike out "*or, at your option, the Life Composition of* £ : : ."

FORM E. (BYE-LAW 7.)

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.

CARD OF MEMBERSHIP.

SESSION 1884–5.

Name.....

MEMBER.

Treasurer .....

Secretary .....

FORM F. (BYE-LAW 7.)

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.

CARD OF MEMBERSHIP.

SESSION 1884–5.

Name.....

ASSOCIATE.

Treasurer .....

Secretary .....

FORM G. (BYE-LAW 7.)

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.

CARD OF MEMBERSHIP.

SESSION 1884-5.

Name.....

GRADUATE.

Treasurer .....

Secretary .....

FORM H.

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.

CARD OF MEMBERSHIP.

Name.....

HONORARY MEMBER.

Date.....

Signed.....*President.*

FORM E E. (BYE-LAW 7.)

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.

CARD OF MEMBERSHIP.

SESSION 1884–5.

Name.....

LIFE MEMBER.

Treasurer .....

Secretary .....

FORM F F. (BYE-LAW 7.)

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.

CARD OF MEMBERSHIP.

SESSION 1884–5.

Name.....

LIFE ASSOCIATE.

Treasurer .....

Secretary .....

FORM J. (BYE-LAW 9.)

SIR,—I am directed by the Council of the North-East Coast Institution of Engineers and Shipbuilders to draw your attention to

Bye-Law 6, and to remind you that the sum of £ of your annual subscriptions remains unpaid, and that you are in consequence in arrear of subscription.

I am also directed to request that you will cause the same to be paid without further delay, otherwise the Council will be under the necessity of exercising their discretion as to using the power vested in them by the Rule above referred to.

I am, Sir,

Yours faithfully,

Secretary.

FORM K. (BYE-LAW 9.)

Sir,—I am directed by the Council of the North-East Coast Institution of Engineers and Shipbuilders to inform you that in consequence of non-payment of your arrears of subscription, and in pursuance of Bye-Law 9, the Council have determined that unless payment of the amount (£) is made previous to the day of next, they will proceed to declare that you have ceased to be a member of the Institution.

But, notwithstanding this declaration, you will remain liable for payment of the arrears due from you.

I am, Sir,

Yours faithfully,

Secretary.

FORM L. (BYE-LAW 10.)

Sir,—I am directed by the Council of the North-East Coast Institution of Engineers and Shipbuilders to inform you that they feel it their duty to advise you to withdraw from the Institution, or otherwise they will be obliged to act in accordance with Bye-Law 9 (or 10, as the case may be.)

I am, Sir,

Yours faithfully,

Secretary.

FORM M. (BYE-LAW 11.)

BALLOTING LIST.

PRESIDENT.—ONE NAME only to be returned, or the vote will be lost.

_____ President for the current year, (eligible for re-election.)*

_____
_____ } New Nominations, from whom to select ONE.
_____

VICE-PRESIDENTS.—SIX NAMES only to be returned (including the four remain in office), or the vote will be lost.

_____
_____ } Four Vice-Presidents remaining in office, whose seats are NOT va
_____
_____

_____ } Two Vice-Presidents retiring, and NOT eligible for re-election.
_____

_____
_____ } New Nominations, from whom to select TWO names.
_____
_____

TREASURER.—ONE NAME only to be returned, or the vote will be lost

_____ Treasurer for the current year, eligible for re-election.

_____
_____ } New Nominations, from whom to select ONE.
_____

COUNCILMEN.—FIFTEEN NAMES only to be returned, including the ten remain in office.

_____
_____
_____
_____
_____ } Ten Councilmen remaining in office. These do not require to be for at this election, as their term of service has NOT yet ex
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_____
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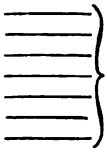
_____

* To be crossed out before issue, when the President is not eligible for re-election

Five Councilmen retiring, and NOT eligible for re-election.



New Nominations, from whom to select FIVE.

N.B.—(*a*) The names of those who remain in office will be counted in the total number required without being re-written by the voter.

(*b*) Any list having either MORE or LESS than the required number of names voted for in any section will be disqualified for that section.

(*c*) Votes as President for a person who is not elected will count for him as a Vice-President.

(*d*) Votes as Vice-President, or Treasurer, for persons not so elected, will count for them as Councilmen, unless they have just completed a term of office in that capacity.

(*e*) This list, duly filled in, may be returned to the Secretary by post, or handed to him, so as to be on the Council table before the commencement of the scrutiny, which is appointed to take place in the Council Room, at 8 p.m. on
18

(*f*) A copy of this list shall be posted at least Seven Days previous to the Annual Meeting to every Member and Associate, who may erase any name or names from the list and substitute the name or names of any other person or persons eligible for such respective office, but the number of persons on the list after such erasure or substitution must not exceed the number to be elected to the respective offices.

Secretary.

FORM N. (BYE-LAW 24.)

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.

VISITOR'S CARD.

PLEASE TO ADMIT

Mr. .....

to the General Meeting, to be held on

.....

.....*Secretary.*

FORM K. BY-LAW II.

BALLOT LIST.

PRESIDENT.—ONE NAME only to be returned, or the vote will be lo

——— President for the current year, eligible for re-election.)*

———

———. New Nominations, from whom to select ONE.

———

VICE-PRESIDENTS.—TWO NAMES only to be returned (including the fo
remain in office, or the vote will be lost.

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———
———) Four Vice-Presidents remaining in office, whose seats are NOT v

———. Two Vice-Presidents retiring, and NOT eligible for re-election.

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———
———) New Nominations, from whom to select TWO names.

TREASURER.—ONE NAME only to be returned, or the vote will be lo

——— Treasurer for the current year, eligible for re-election.

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———
———} New Nominations, from whom to select ONE.

COUNCILMEN.—FIFTEEN NAMES only to be returned, including the te
remain in office.

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———} Ten Councilmen remaining in office. Thes
for at this election, as their term of se

* To be crossed out before issue, when the President is

FORM O. (BYE-LAW 47.)

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.

FORM OF PROXY,

FOR VOTES ON ALTERATIONS TO CONSTITUTION OR BYE-LAWS.

I,....., being [an Honorary Member, Member, or Associate] of the above Institution, do hereby appoint Mr....., who is [an Honorary Member, Member, or Associate] of the same Institution, to act as my Proxy, and record my Vote at the General Meeting of the Institution, to be held on the ..... day of ....., 18....., and at any adjournment thereof.

Signature.....

Address .....

.....

.....*Secretary.*

NORTH-EAST COAST INSTITUTION

OF

ENGINEERS AND SHIPBUILDERS.

GENERAL MEETING, NOVEMBER 28, 1884, HELD IN THE LECTURE HALL OF THE LITERARY AND PHILOSOPHICAL, SOCIETY, NEWCASTLE-UPON-TYNE.

W. BOYD, Esq., President, in the Chair.

The President, in opening the proceedings, said, he felt he had not sufficiently made it apparent how thoroughly and how very strongly he recognised the compliment paid to him in electing him to the office he now held. The difficulty in such cases lay in not being able to convince the hearers that what was said was sincere. Many a man had expressed himself as feeling very incompetent for the post he was called upon to occupy, whereas, perhaps in his inmost soul, he thought you could not have got a better man. Probably the truth would be found somewhere between. He could not confess he felt thoroughly incompetent, but at the same time his conscience would not allow him to say that they could not have got a better man. He hoped the Institution which they inaugurated that night, had a great future before it, and he would yield to no man in his appreciation of the future and the great career that he felt lay before them, and he would yield to no man in his anxiety to carry forward and assist it to his utmost.

PRESIDENT'S INAUGURAL ADDRESS.

GENTLEMEN,

It has been suggested, that in the case of this newly-formed Institution, with its still unwritten history, the proceedings should undoubtedly be inaugurated by some remarks from the Presidential chair. Desirous to satisfy, however imperfectly, any wishes of this kind that lie within my powers, I propose to ask your attention for a short time this evening.

The treatment that has recommended itself to me is to address myself for a few moments to put on record as a matter of future interest the steps which have led to the formation of our Institution in its present form, or, in other words, to trouble you with a short retrospective narrative, and then to lay before you some thoughts which have passed through my mind as to the future aims and objects which the members of the Institution may profitably keep in view.

Leaving then in the obscurity of the past those vague conversations and indefinite aspirations which I know have passed in days gone by among some of those who are now members of this Institution, and in which the want of such a society in this north-east district of ours was generally admitted, I believe I am correct in saying that these conversations and these aspirations first assumed tangible shape in a letter which appeared in the *Newcastle Daily Journal* of March 17th, 1884, above the signature of your present Honorary Secretary, Mr. W. G. Spence, disguised in the *nom de plume* of "T Square."

Some time elapsed before anything further was apparent, but your Secretary and his friends were not altogether inactive, and, on September 19th, a private meeting of nine junior members of the professions of engineers and shipbuilders was held, which resulted in circulars being issued, soliciting support in the formation of a Society for the reading and discussion of technical papers on subjects of interest in their daily work. This circular was issued in the names of the following gentlemen—and I think it is right that they should be recorded in the annals of the Institution—viz., Messrs. W. G. Spence, Weir, Green, Williams, Sinclair, Stevenson, Millar, Winstanley, and Milne.

The issue of this circular resulted in a meeting held in the Surgeons' Hall on October 8th, 1884, when the chair was occupied by one of your Vice-Presidents, Mr. C. W. Hutchinson. At that meeting our Society was practically inaugurated; and though many important modifications have since been made, the foundations of this Institution, which we all hope will yearly grow in importance, and some day obtain for itself a recognised position among similar societies, were then virtually laid.

But an idea that possesses inherent virtue and a scheme that even unwittingly supplies a want hitherto unfelt and unacknowledged, is apt to develop with a rapidity and strength of growth quite unexpected: and this has been the case here. Another circular was issued, indicating in outline the constitution of the proposed Institution, and while much thought was being bestowed upon the best means of effecting a union between what I may describe as the senior and junior members of our profession, it was soon apparent that instead of any great difficulty being found in bringing this about, the elements and the inclination for such union were not far to seek.

A public meeting was held in the Surgeons' Hall on October 22nd, over which I had the honour to preside, which was very largely attended, and at which the formation of such an Institution was warmly advocated; and I think I may say that at that meeting three key-notes were struck of great importance to our future well-being.

(1) That our aims should be high—that we should not be content with a mediocre position, either as to number of members or the scope of our proceedings; and that, while room should be found for those who had still to win their spurs in the professional conflict, yet that the Institution should also seek the adhesion of those others whose greater information and extended experience would entitle them to be heard.

(2) That in our papers and discussions we should, young and old, meet on equal terms. That he whose position amongst us is to be recognised as the highest shall be the man whose brain is the clearest, whose intellect is the keenest, and whose powers of expression shall best compel the respect and the concurrence of his hearers.

(3) Lastly—but by no means least—it was unanimously felt that the Institution should embrace not only the Tyne, but the Wear and

the Tees, those centres being possessed of men as eminent and as capable as any that the Tyne can boast of, and, consequently, if the Institution was to be a success, their support was absolutely necessary.

At this meeting the number of the previously-formed Provisional Committee was largely increased, several representatives from Sunderland being added thereto, and, under the chairmanship of Mr. C. W. Hutchinson, long and arduous have been their labours. It is, however, unnecessary that I should trouble you with them in detail here. They were fortunate in securing not only the adhesion, but, if I may use the term, the enthusiastic support of the men of Sunderland, and their deliberations resulted in many important modifications in the proposed constitution; these were presented to the meeting of November 20th, 1884, when the outline of the future constitution was finally determined upon, and when the Provisional Committee transferred their duties to the Council appointed at that meeting.

In their hands the conduct of your Institution now rests, and perhaps I may be excused if I say one word to plead for your support and assistance to that body. I would remind you that they are elective, and the direct representatives of the body of the members. Mistakes they will doubtless make—no human organization can be free from them; but, gentlemen, I entreat you, give them your confidence. A substantial proportion will come before you yearly to ask your approval of their management, and on such occasions your voice can be constitutionally heard; but in the intervals give them the credit of being actuated solely with the desire for the best interests of the Institution, since without that generous confidence their labours will indeed be in vain.

If I am not wearying you, may I now say a few words as to the future?

What are the objects and aims which we should set before us, and what are the objects and aims for which we have banded ourselves together? To use the words of our constitution, these are: "The advancement of the science and practice of engineering and shipbuilding, and the interchange of ideas and information among its members, by means of meetings for the reading and discussion of papers relating thereto, and placing on record its transactions." And as you have seen fit to elect me to the position I now occupy, may I

be pardoned if I endeavour to indicate briefly some subjects to which, in my opinion, your attention may profitably be directed?

Although it has, I think, been wisely decided that our doors should be open to all branches of engineering, it must be admitted that our principal and chief *raison d'etre* lies in the subject of Naval Architecture, embracing by that term not only the hull of the vessel, but the machinery of propulsion and all other contingent or contributory appliances.

In this great industry, upon which we on this north-east coast are so largely dependent, we see ourselves face to face with a foreign competition, daily becoming keener and more difficult to meet. To the consideration of such matters I trust I am not too sanguine in hoping that our senior members will be valuable contributors; and especially in such discussions will a place be found for our associate members, shipowners, and others, not perhaps directly occupied in our profession, but whose acquaintance with the problems to be solved, and of the condition under which only can success be achieved, will doubtless stimulate us in our endeavours to produce vessels of various kinds and to serve various purposes, which may in their commercial and economical results lend increased prosperity to our undertakings.

I imagine that no shipbuilder or naval architect among us will contend that the best type of vessel is already designed, and that the ship of to-day is incapable of improvements. The most cursory examination of the subject will convince to the contrary.

The simple fact of the appointment of the Load Line Committee, and the more recently appointed Committee on Merchant Shipping, proves that a multitude of questions affecting our commercial fleet are open for debate.

I cannot but feel considerable hesitation in approaching this part of my subject, from the consciousness that it is not exactly my own department of work, and that we have among us many men much more capable of dealing with it than I can hope to be, notably one of our Vice-Presidents, whose published works are regarded among the text-books of the science, and whom I now gladly venture to take this opportunity of welcoming to the North of England.

Probably the question which among others towers pre-eminent is that of *stability*; and it is right that it should be so, seeing that this

question involves that which many others do not, viz., the safety or risk of human life. It is, I suppose, an admitted fact, that in the last few years the tendency has been more in the direction of increased beam relatively to other dimensions than was formerly the case, and that the narrow deep ship of a few years back is giving place to proportions, probably embodying greater safety. But may it not be that danger and risk have arisen in some measure from insufficient knowledge and information supplied by the shipbuilder, to the shipowner and his captain, of the character and capabilities of the vessels placed in their hands, and that as more attention is given to the best proportions, and more information placed in the hands of those in charge, we may reasonably expect to see a diminution in the number of *preventible* losses at sea? Already one of our members has designed appliances calculated to make the stability of a vessel, under varying conditions of load, more evident to those in charge at sea; and the efforts of another have been directed to bring into more general use simple methods of calculation and of graphic demonstration of scientific shipbuilding.

There is, moreover, no reasonable room for doubt that we are in a transition stage as regards the material used in the construction of our steamers, and that year by year an increasingly large number will be built of steel. Hitherto, we in this district have laboured under some disadvantage in this respect; but now that we see the existing works of Bolckow, Weardale, Consett, and Palmer increasing their capabilities, and the newly-established steel works at Elswick rapidly approaching completion, we may hope that in this respect the shipbuilders of the Tyne and Wear will, before long, be placed in as good a position as their brethren on the Clyde.

It would be impossible in the time at my disposal to enumerate all the interesting and novel questions which present themselves to the shipbuilder of to-day, but two others I may perhaps mention. One is, improvements in the loading and discharging of cargoes by the substitution on the deck of the vessel itself of hydraulic instead of the ordinary steam appliances, a system which has lately been much brought before the shipping world, its introducers claiming for this arrangement a smoothness of working, economy and rapidity of action not obtainable by any of the present methods. Forming almost part

and parcel of the same subject, inasmuch as it tends to reduce the time during which any vessel lies unoccupied, or what has been happily designated the "dead life" of a steamer, is found in the system of lighting by electricity. The advancement in practical electrical science has been so rapid of late, and electrical appliances are now obtainable at so much lower cost than formerly, that we find a great increase in the number of passenger vessels supplied with this luxury ; but probably before very long, as the cost of the first installation is still further reduced by healthy competition, and by improved and more economical production, we shall see the system more and more largely employed for giving light during the loading and discharging of ordinary steamers, and I draw this conclusion with the more certainty as the manufacture of such appliances has been lately entered upon by a well-known firm of engineers in our own neighbourhood.

I cannot leave this part of my subject without showing that I have in my mind that highest branch of naval architecture which has lately made a home among us, and which we trust may, as time goes on, add to the reputation of Father Tyne. Of course I allude to vessels of the "Esmeralda" type, and the cruisers and vessels of war, of which we have all heard so much of late in the public prints. These vessels are so entirely a speciality, and their construction and equipment so much out of the ordinary experience of most of us, that we can hardly regard them as very likely to furnish many subjects for discussion or criticism here. We may hope, however, that the building of these and of vessels of much larger and heavier types will add much to the wealth, prosperity, and fame of our locality.

Nor when we come to the department of engineering is the field before us one whit less extensive or interesting. The history of the science or profession of engineering and shipbuilding shows us at once that any great step in advance has generally occurred in periods when the profitable employment of the article produced became increasingly difficult. Through such a period we are now passing, and it behoves us all to use our utmost endeavours to turn it to the best account both for ourselves and others. It is nothing new to tell you that men's minds are now being directed towards the profitable and practical employment of higher working pressures of steam in steamships, and to

the adaptation to commercial and everyday use of the advantages derived from the use of forced draught in order to obtain a superior combustion of the fuel used.

That some degree of success in the direction of the employment of higher steam pressure has been attained is a matter that admits of no doubt, and I venture to record my opinion that the triple expansion engine, working on three separate cranks, is destined to become the marine engine of the future. The use of steam expanded something like ten or twelve times in the triple expansion engine, as compared with, say, six or seven times in the ordinary compound engine, seems likely to afford in practice an economy fully equal to that theoretically due to the employment of the higher pressure, and the subdivision of the rotary effort on the crank shaft, by attaching three separate cylinders to three separate cranks, and thus increasing the number of the points of initial pressure from four to six in each revolution, seems, in my opinion, to promise a more even distribution of the effective power, and consequently a smoother working piece of machinery than we can hope to possess in the ordinary compound engine.

To illustrate my meaning on the latter point more fully, I may be permitted to add that I recently saw a triple expansion engine working on three separate cranks, and with a working pressure of 150 lbs. in the boilers, revolve smoothly and continuously and without stoppage at twelve revolutions per minute, and I believe this is a result not obtainable in an ordinary compound engine. This indication of equalization of strains and consequent smoothness of working will at once commend itself to all practical men.

Whether we shall find ourselves stop short with an expansion of, say, twelve times, as in the present triple expansion engine, with a working pressure of 150 lbs., or whether, as may very possibly be the case, we shall advance to fifteen or seventeen ratios of expansion by the employment of four cylinders of increasing diameter, and a working pressure of 200 or 250 lbs., remains to be seen; but before this can be done some material modification will be necessary in the boilers at present in use.

At present, in order to comply with Lloyd's regulations for a working pressure of 150 lbs., the shell plates of a steel boiler 13 ft. diameter

must be $1\frac{3}{16}$ thick, and I believe that such a thickness of plate presents something like the maximum that can be satisfactorily dealt with in practice, so as to ensure a permanently steam and water-tight structure, having in view the variation of temperature and the consequent unequal expansion that must of necessity exist between the top and the bottom even of boilers of the best and most careful design. If, therefore, a further advance is made in working pressure, boilers of small diameter and greater length and different designs must be contemplated, and probably the "straight through" boiler, with the small tubes leading directly from the furnace-box, or what is commonly called the Admiralty type of boiler, will be most likely to come into use.

If this be so, serious modifications must necessarily follow in the arrangement of the space allotted in vessels for the engines and boilers, and then will come into play the combined efforts of the naval architect and the marine engineer, to design such a combination that the space at their disposal shall be economized in every possible way, so that the carrying capacity of the vessel be not sacrificed to improvements in the propelling power.

The other point of forced draught, to which I have alluded, is still more in its infancy, but it by no means follows that it may not shortly grow to strong and vigorous manhood. The advantages which have been obtained in vessels of war from the employment of this system under certain conditions are so very great that I am led to hope that before long the stimulus of healthy competition, and the desire for improved results, may contrive some adaptation of that or similar systems to the mercantile marine. I may refer those present to a paper read by Mr. Howdon, of Glasgow, on this subject, before the Institution of Naval Architects, in April of this year, describing an arrangement which is now in practical operation at sea, with the prospect of the most successful results; and whether the adaptation of the system assumes this or any other form, I feel much confidence in commending the consideration of the matter to your earnest attention, believing as I do that it affords a wide field for inquiry and a promise of results perhaps hitherto uncontemplated.

There is one other matter of the most vital interest to both shipbuilder and engineer to which I beg your attention both now and

hereafter, viz., the proportion that the indicated power developed by any system of machinery bears to the effective power usefully employed in propelling the vessel. In *Engineering*, under date October 17th, 1884, is recorded a most interesting account of a series of trials held on the United States Fish Commissioners' steamer, "Albatross," in which vessel a series of apparently elaborate and careful experiments were made to determine, with accuracy, how much of the total indicated power was usefully employed in the propulsion of the vessel. These figures and calculations are open to reference by any of you, and hence I will not trouble you with them at length, but it would appear to be clearly shown that, while the engine developed 457·5 indicated horse-power, only 289·6 indicated horse-power was appropriated for the propulsion of the vessel, or, say about 63 per cent., the remainder being absorbed in the friction of the engine and pumps, friction of the propeller on the water, and slip of the propeller. Is this conclusion correct? and if so, is the result not in some way capable of improvement?

I have hitherto spoken of "Improvement in the article produced," and I would now say one word on the subject of "Economy in production."

In the address which my friend Mr. Westmacott delivered, as President of the Institute of Mechanical Engineers, in 1882, he made use of the following pregnant words, "Never undertake the smallest piece of work without wrapping it round with economy."

Now, economy is of two kinds—the *true* and the *false*; and it by no means follows that because a "piece of work" is cheap, that it is therefore economical; but if we steadfastly set before us to produce nothing but what shall be efficient and perfect for the service in which it be employed, then economy in its production cannot be other than a gain.

This practical direction for our efforts is one that must commend itself to all, from the oldest to the youngest; for while circumstances may render it possible for only the older among us to deal with some of the broader or larger questions involving commercial and general issues, into the consideration of which many matters contribute, yet there is no piece of machinery and no part of a vessel so insignificant but that some improvement may be effected in its economical

production, and it is in this department that the efforts of designers, foremen, and others may be employed with the utmost advantage, and may be fruitful of results little contemplated at the outset of their labours.

Permit me to allude to one or two points to exemplify my meaning.

Without entering into any vexed trade questions, it is an acknowledged fact that the sums paid to ironworkers employed in the construction of iron vessels is out of all proportion to those earned by men of their class in other trades, and that, as a consequence, the building of the hull of a ship becomes a most costly operation.

Now, the "closing" of the heated rivet has for some years past been accomplished in boiler-building establishments by hydraulic, steam, or other mechanical agencies, and it becomes an interesting question to discover what really stands in the way of the application of similar appliances to rivet up the hull of an iron ship.

Already more than one system is in use in the shipyards of the Clyde and the North-East Coast to rivet the keels, beams, and frames of iron vessels by hydraulic appliances, but these systems have not hitherto been incorporated into daily work or common use; one reason being, I think, that they are at present only capable of partial application in the work of an ordinary shipyard.

The present design of constructing an iron ship, with its vertical frames and reverse bars, and horizontal lines of plating, seems to shut the door to the hydraulic rivetter, and prevent the shipbuilder calling this class of machinery to his assistance. But is the present construction of the ship capable of no alteration or improvement? It is true the design is to all intents and purposes universal, but is it, therefore, necessarily the best? I am of opinion that the naval designer who can propose a method of construction which shall admit of greater employment of mechanical contrivances in the building of his hull, while at the same time he carefully retains a form of structure capable of resisting the varying strains which are thrown upon it, will, by promoting economy in production, stimulate demand for the article produced, to the great advantage of all classes of the community.

There is another matter in an ordinary shipyard which to the mechanical mind seems to afford great scope for economy. I mean the transport of materials from the furnaces and bending blocks and

punching machines to their places in the completed structure. The present system of hand bogies, laboriously hauled across the yard by a gang of men, the adjustment of the blocks and chains, and the spasmodic efforts by which the frame of the ship is eventually upreared, or the plating finally reaches its destined place, is, of course, familiar to us all. Again, I ask, are these matters capable of no economical improvement?

In the workshop of the engineer the same thing holds good. Are not the large majority of our machine tools capable of some improvement which shall greatly increase their power of production? In the position of the cutting tool, in the speed at which the machine is driven, in the care with which the character of the machinery is adapted to the work it has to perform, we may all find abundant field for the occupation of all the mechanical and scientific skill and experience with which we may be fortunately endowed.

In fact it resolves itself into a question of "enthusiasm." If a man sets himself to consider with how little work or how little trouble and exertion he can earn his yearly stipend, the result is of one kind; if, on the other hand, he be an enthusiast in his occupation, and the constant study of his life is, how much, not how little, he can accomplish, then the result is widely different, and fortune (proverbially fickle) is indeed ungracious, if as years go on, a man of this nature does not find himself passing in the race of life those who started on equal terms with himself. But be the result what it may, he will at any rate be possessed with the consciousness of having done his best with those talents which God has given him.

Finally, one word as to the character of our Papers and Discussions.

I was reading lately an account in an Engineering paper, of a recent meeting of the Cleveland Institute of Engineers, in which the opinion was expressed that *local* institutions were less and less likely to flourish, for the reason that the two great engineering institutions of the country, the Civil Engineers and the Mechanical Engineers, with their head-quarters in London, were found to supply all the requisite information desired by professional men. I venture to differ *in toto* from this conclusion.

If the publication of papers was everything, it might be so; but this view of the case leaves out of account altogether the discussions

on the papers read, and to my mind this is a most important element. We cannot all attend meetings in London, and the formation of such a society as this will, I believe, afford opportunity for bringing to light many a half-formed conception, and many a crude idea, the necessary condensation and clear exposition requisite for the presentation of which, in the form of a paper, will give life and real existence to that which was before, perhaps, but vague and ephemeral. Those who have ever tried their hands at writing a paper for any scientific body, will bear me out in the statement that no other process has the same educational value to the writer himself. It renders necessary a thoroughness of knowledge and perfect acquaintance with the subject in hand, obtainable by no other method I know of.

Papers need not, however, be lengthy. The best and most valuable discussions often arise from the shortest paper, but writers should, I think, be careful that the subject on which they discourse must be their own, and not in any way the property of others, and also that the aim of their efforts should be the exposition and elaboration of scientific and practical truths, unmixed with any underlying intentions of a different character.

The free and frank discussion of such papers, guarded by consideration of the views and feelings of others, and clothed in clear and appropriate words, must, I feel sure, be of incalculable benefit not only to the speaker himself, but to his hearers. A habit of concise expression and clear description will thus be promoted, which will bear fruit not only in our meeting, but in the intercourse of everyday life; and it is with the earnest hope that our proceedings may bear the character which I have thus feebly endeavoured to depict, and that no word may be spoken and no act committed among us, other than that which shall be worthy of English gentlemen, that I now beg most sincerely to thank you for the patience and courtesy with which you have listened to my remarks.

Mr. C. W. Hutchinson begged to move a vote of thanks to the President for the very valuable paper he had given them. He would call the attention of the meeting to a very beautiful instance of natural selec-

tion as to two officers of the Institution. The President had referred to a letter, a copy of which he had with him, which was published in March last in the *Daily Journal*. It read:—

SIR,—Is it at all creditable to a community so largely interested in engineering and shipbuilding that no Association similar to the Institution of Engineers and Shipbuilders in Scotland exists in this district? There is certainly no lack of talent or energy on Tyneside, and in a profession so full of interesting matter there could be no want of subjects for discussion. It is well known a valuable society, restricted to foremen engineers and draughtsmen, exists and flourishes; but there is great room for an extension, which would include either in a graduate section, or some such form, a division more immediately in contact with the younger members of the profession. The present would appear to be a favourable season to move in the matter, so that a meeting might be called and a committee formed to arrange about papers, etc., during the summer, so that a session might be inaugurated next winter. I am sure this is a subject which only requires to be mentioned to commend itself to all members of the kindred professions. An expression of opinion through your columns might ultimately lead to the formation of such an institution. —I am, etc.,

"T SQUARE."

On the day of the issue of that letter a reply was penned, the writer of the reply not knowing who "T Square" was; and the reply appeared in the *Journal* next day, in the following words:—

SIR,—The letter appearing in your issue this morning, signed "T Square," may, so far as the *nom de plume* is concerned, be a puzzle to those of your readers who are not acquainted with the mysteries of a drawing office. Your correspondent has, however, alluded to a want which ought not to be allowed to exist any longer in this important shipbuilding and engineering district. What might be the best form that the scheme should take, especially in reference to the existing Association of Foremen Engineers and Draughtsmen, would be a subject for future consideration; but I think that if your "square" friend were to make himself known he would find many willing and anxious to help him. I, for one, would gladly do what I could.—I am, etc.,

Wallsend Slipway and Engineering Works, W. BOYD.
March 17th, 1884.

A finer instance of proper selection, he thought, could not well be found, since "T Square, the writer of the first letter, is the Honorary Secretary of this Institution, and the writer of the reply is the first President.

MR. ROBERT THOMPSON said, he had very great pleasure in rising to second the motion of a vote of thanks to the President. He was pleased at the able manner in which he had sketched out the work of the Institution. He thought that the quality of the papers rested

with themselves; they were a question of ability, and those who came forward with papers would be the men, he thought, to push to the front.

Mr. William Clark said, he also had very great pleasure in supporting the motion put before them. He was very glad of the opportunity to bear witness of the great trouble Mr. Boyd had been put to, and the able services he had rendered in the formation of this Institution, in fact it could be congratulated most sincerely on its first President. The President in referring to the papers had very wisely, he thought, stated that they had members who were so conspicuous in their profession that their Transactions could not fail to take up a very distinguished position. At the same time, he believed, there would also be another class, probably not quite so ambitious, but which would be of equal value. The notion he had in joining the Institution was, that it was not merely to promote the advancement of shipbuilding and engineering, but to promote the advancement of their own knowledge on these subjects; and he believed there was no Institution more likely to do so than this. One of the original objects in the formation of the Institution was, that those who were actually engaged in the carrying out of the work should have an opportunity of meeting each other, and learning from each other their every-day experience. He believed that workshop practice and results of their work would form as valuable papers as any they were likely to have.

Mr. W. H. White said, there were one or two points in their President's address which claimed their direct attention, if they wished to make the Institution the success that he hoped and believed it would be. He thought that his closing remarks deserved their earnest attention. They did not want papers which, like many French publications, begin at the Creation and end at the Millennium. It was not that kind of paper that would be of service to them, but it was papers that contained clear ideas. They did not want treatises; they were not in place in an Institution like this. They came to discuss something which would advance science or practice, and therefore, something more modest than a treatise. He hoped it would be a feature in the Institution that the contributions of the younger members would be encouraged. The younger members engaged in detailed work were more likely to hit upon something useful than were men

who were older, with their powers of production necessarily limited, as compared with those who were younger, and had their minds freer from responsibility. If the younger members of the Institution could only be content to produce something brief, and pointed, and useful, he was sure their contributions would be welcomed and treated with that consideration which perhaps their own modesty would think their papers scarcely deserved. He hoped this Institution was going to have a great educational effect. He hoped the graduate section would develop into something that would be a credit to the North-East Coast. If they were going to meet foreign competition they must meet it with training. Those who knew what had been done abroad in France, Germany, Russia, and other countries, in that very matter of technical education, must know how great our need was, and he hoped the graduate section would produce a great educational benefit to the district. He trusted that Glasgow was not going to be allowed to remain alone in the possession of a "chair" of Naval Architecture. He had not the least desire to encourage jealousy, but he thought this district was large enough to have its own training both in the subordinate and the higher branches of Naval Architecture and of Engineering. One other remark he wished to make. There was a considerable feeling in some quarters that an Institution such as this might do harm to the legitimate claims of business by publishing information which perhaps had been acquired by a particular firm at great expense. He thought that if the President's golden rule were always observed, and that the writer of a paper was always careful to use only his own property, and not the property of others, the risk, which some people who otherwise wished us well imagined might cause disaster, would be altogether avoided. He hoped he was not discouraging investigation. He was not saying a word against the publication of knowledge —he had no belief in secrecy—but it was necessary, especially for those who might not occupy a first position in business, to be careful not even to give the shadow of suspicion of going beyond that use of knowledge which was legitimate and proper. He would further like to say that he hoped that the existence of this Institution would be in no sense regarded as an attack upon the Institution of Naval Architects in London. There should be, he thought, in London some central Institution, and they ought to regard it as the parent Institu-

tion, and make it in the future a greater success than it had been in the past.

Mr. J. C. STIRZAKER endorsed the remarks already made respecting the interesting address of the President. He thought the younger members would hold back until some of the "seniors" had set them an example, and he considered it would be rather difficult for the junior members to give papers and not to a certain extent infringe upon other people's property. Certainly employers had a chance of giving information which their employés could not have. It was very difficult to make a paper thoroughly interesting without giving statistics of different kinds which, possibly, would not be liked by their employers.

Mr. F. C. MARSHALL said, occupying the honourable position in which the members had been good enough to place him, he might be allowed to put this vote to the meeting. In doing so, they would allow him very heartily to endorse all that had been said by the previous speakers as to the value of the important address to which they had just listened. He was very pleased to hear Mr. Hutchinson as to the inception of this Institution. We learn now, for the first time, that Mr. Spence wrote the first letter regarding it, Mr. Boyd the second, and they were there that night as the result of those two letters. He thought it was only fit that this should be put upon the records of the Institution, because they would observe Mr. Boyd had not named his own letter in his address. He was sure they all felt indebted to their President for the very able address which he had given to them. He was very pleased to hear Mr. Clark mention that even the older men had joined the Institution with a view of learning from their younger men, who had had greater advantages than they had had. He was also pleased to hear Mr. White call the Institution of Naval Architects in London the parent Institution, and trusted that this would be a worthy child of that useful and valuable society. He wished distinctly to emphasize one point—that they were not a Tyneside Institution, nor a Wear Institution, but the North-East Coast Institution; and it was their earnest desire that their friends on the Tees, and if possible, those at Hull also might join them, and that they would feel the necessity of this Institution, and advance its interests. He most sincerely endorsed

the remark of Mr. White with respect to the "Graduate" section of members; the older members should seek to bring the younger men to their meetings. He had had something to do with bringing forward the subject of a "chair" of Naval Architecture. He did not know whether it was fully noticed in the papers, but at the last general meeting this subject was brought before the College of Physical Science. It was intimated to the meeting that a sum of £750 had been deposited by the trustees of the "North-East Coast Exhibition," and was now bearing interest at the rate of four per cent., which interest was to be devoted for the moment to a Scholarship in connection with the College, but the capital remained at the disposal of the College for the formation of a "chair" of Naval Architecture for this district. He might say that the terms on which this Scholarship was to be awarded were now under consideration, and would be published before the end of next month, and persons will be invited to compete for this Scholarship in the College, before the 1st January. He had not the authority of the College for saying so, but that was the arrangement the last time he had the pleasure of speaking about the subject. One might, had time permitted, go into the technical questions raised in the address where, probably, one would be more at home than talking in this general way. The questions of high-pressure steam, of four cylinders *versus* three cylinders, of three cylinders *versus* two cylinders, or no cylinders at all *versus* cylinders (because he had had the pleasure of seeing an engine within the last fortnight which performed its duties with as great an efficiency as any ordinary high-pressure engine, which had no cylinders, and which ran at 16,000 revolutions per minute). We might go into other points, forced draft, for instance, to which the President had alluded. He had the impression that forced draft was born in Newcastle, and he thought they would all agree with him that their great predecessor and ancestor, George Stephenson, was the first man to apply forced draft to steam engines; Newcastle was, therefore, the birth-place of forced draft; but these subjects were rather matters to be dealt with as separate papers to be read and discussed than for general remarks on the motion of thanks to the President, which motion he had much pleasure in supporting.

The motion was then put to the meeting and carried, with applause.

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.

FIRST SESSION, 1884–85.

GENERAL MEETING, DECEMBER 22, 1884, HELD IN THE LECTURE HALL OF THE LITERARY AND PHILOSOPHICAL SOCIETY, NEWCASTLE-UPON-TYNE.

W. BOYD, ESQ., PRESIDENT, IN THE CHAIR.

ON THE SPEED-TRIALS OF STEAMSHIPS.

BY W. H. WHITE.

THE object of this paper is to illustrate and emphasize the value of properly-conducted speed-trials of steamships. In order to do this it will be necessary to refer to some misconceptions which appear to exist amongst both shipowners and shipbuilders respecting the nature of the information obtainable from these trials, and to briefly discuss some important matters affecting the conduct of speed-trials or the analysis of their results. It may well happen that in traversing such oft-trodden ground little that is novel will be said; but in choosing the subject for the first paper read before this Institution it appeared desirable to select one which can scarcely fail to be interesting to members and associates of all classes, and which may possibly, by its discussion, exercise some beneficial influence upon the general practice of shipbuilders and engineers in this district.

Coming into the neighbourhood recently as I have done, and seeking to become familiar with current practice, I have been greatly impressed by the comparatively small attention given to the speed-trials of by far the greater number of steamers built on the Tyne and Wear. It is probably no exaggeration to say that, with few exceptions, the trials made under-weigh, before ships leave for their first voyage, are

designed rather to test the completeness and efficiency of the propelling machinery, than to afford any indication of the speed or economical performance of the ships. They are usually tried in a very light condition, and although they may be run a few times over the measured mile during the trial trip, no attempt is made to obtain exact and detailed information respecting the efficiency of the engines and the propellers. It is but right to add that, although this is the common case, there are notable exceptions to the rule; and in recent years some of the most exhaustive and complete series of "progressive trials" ever made have been conducted on the Whitley measured mile.

When enquiry is made into the reasons for the general neglect of speed-trials for the cargo-carrying steamers which are the staple product of the North-East Coast, one learns, as might be expected, that there is much to be said in favour of common practice. First of all, there is the undoubted fact, resting on the experience of many years, that within the limits of their working speeds—say 8 to 10 knots per hour—cargo steamers require wonderfully small expenditures of coal and engine power for their propulsion. Owners may be pardoned if with this experience in their possession, they have not cared much for more elaborate smooth-water trials. Again, it must be allowed, that the enormous carrying-power of such steamers—the large amount of dead-weight which has to be put on board to bring them to their load-draughts—makes it difficult in most cases, and practically impossible in not a few, to try the speed of new ships (before they pass into actual work), at draughts of water approaching the load draughts. Furthermore, the desire to lose no time in setting a ship to work immediately that she is ready is a very natural one; and there are often occasions when delays of a serious nature would be incurred in waiting for suitable weather and a fairly smooth sea, to make the trials on the mile off Whitley. In this last-mentioned matter we on the North-East Coast are at a great disadvantage, as compared with our fellow-workers on the Clyde, or with the professional officers of the Royal Navy; but we must accept the disadvantage, since it is not possible to find such sheltered waters as Skelmorlie or Stokes Bay within easy reach of the Tyne and Wear.

To the foregoing reasons for the comparative rarity of speed-trials in this district, may be added another to which, in my judgment, far

less weight should attach, although it is probably the most influential. I refer to the feeling of distrust, if not of contempt, entertained by large numbers of shipowners and shipbuilders for trials made under measured mile conditions. It is often said that the true test of efficiency is to be found not in trials made in smooth water for short periods, with engines and boilers at their best, with picked coal, and clean painted bottoms, but in the results of a long series of voyages under varying and trying circumstances of wind and sea, with ships, machinery, and coals all under ordinary working conditions. Now, no one is less likely than myself to question the great value of experience of the kind described: and I would add that such experience may often be a necessary corrective to some deductions made from measured mile trials. On the other hand it must be as strongly asserted that for many of the most difficult and important problems which the shipbuilder and engineer has to face, the only possible practical solutions are to be found in speed-trials made under fixed and carefully ascertained conditions, such as are obtainable alone on the measured mile. These measured mile trials do not furnish all the information needed for guidance in the designs of later ships, and for assistance in the progress of improvement. Other experiments, either on the ships themselves, or preferably on models of the ships, are required to determine the resistance offered by the water to their passage, and to enable exact comparisons to be made between different forms. To such resistance-experiments allusion will be made hereafter: but confining attention to measured mile trials I would reiterate the opinion expressed above, and add that, besides being a necessity to the shipbuilder and engineer, they are the source of substantial advantage to the shipowner. In support of this contention a short statement will suffice.

In treating of the efficiency of a steamship it is necessary to consider separately the following points:—

1st. The magnitude of the resistance which is offered to her movement through the water at various speeds, and particularly the magnitude of the resistance experienced at the highest speeds for which the ship is designed.

2nd. The efficiency of the propelling machinery at all speeds up to the working or maximum speeds.

3rd. The efficiency of the propellers.

designed rather to test the completeness and efficiency of the propelling machinery, than to afford any indication of the speed or economical performance of the ships. They are usually tried in a very light condition, and although they may be run a few times over the measured mile during the trial trip, no attempt is made to obtain exact and detailed information respecting the efficiency of the engines and the propellers. It is but right to add that, although this is the common case, there are notable exceptions to the rule; and in recent years some of the most exhaustive and complete series of "progressive trials" ever made have been conducted on the Whitley measured mile.

When enquiry is made into the reasons for the general neglect of speed-trials for the cargo-carrying steamers which are the staple product of the North-East Coast, one learns, as might be expected, that there is much to be said in favour of common practice. First of all, there is the undoubted fact, resting on the experience of many years, that within the limits of their working speeds—say 8 to 10 knots per hour—cargo steamers require wonderfully small expenditures of coal and engine power for their propulsion. Owners may be pardoned if with this experience in their possession, they have not cared much for more elaborate smooth-water trials. Again, it must be allowed, that the enormous carrying-power of such steamers—the large amount of dead-weight which has to be put on board to bring them to their load-draughts—makes it difficult in most cases, and practically impossible in not a few, to try the speed of new ships (before they pass into actual work), at draughts of water approaching the load draughts. Furthermore, the desire to lose no time in setting a ship to work immediately that she is ready is a very natural one; and there are often occasions when delays of a serious nature would be incurred in waiting for suitable weather and a fairly smooth sea, to make the trials on the mile off Whitley. In this last-mentioned matter we on the North-East Coast are at a great disadvantage, as compared with our fellow-workers on the Clyde, or with the professional officers of the Royal Navy; but we must accept the disadvanta[illegible] it is not possible to find such sheltered waters as Skelmorlie or [illegible]y wi[illegible] in easy reach of the Tyne and Wear.

To the foregoing reasons for the comparative ra[illegible] in this district, may be added another to which, in

Speed-trials show, it is true, the aggregate effect of these three sources of expenditure of power, but it will be convenient to glance at each.

As regards the first section—the nett or tow-rope resistance of the hull—a few words may be added. For a completed ship at her working draught this resistance is a quantity fixed and defined, so far as the influence of *under-water form* is concerned. Changes in trim (fore and aft) may somewhat influence resistance, but probably in most cases the principal effect of such changes is seen in their influence on the performance of the propellers. What is of the greatest importance, however, is the condition of the wetted-surface of the bottom, that is to say, its cleanness and smoothness, or its foulness and roughness. In all ships frictional resistance plays a prominent part: in cargo steamers of moderate speed, the condition of the bottom is by far the most important factor in the resistance. Frequent cleaning and painting is an undoubted economy: a small degree of foulness costs dearly. Having regard to these facts it is clearly evident that one essential condition to all speed-trials is that vessels so tried should have clean bottoms; since it is only when this condition is fulfilled, in association with an assigned draught, that any fair comparisons can be made and any scientific deductions attempted. And since variations in the condition of the bottom of a ship are certain to occur in actual service, while they cannot be accurately known or allowed for, it is evident that on this account records of performance on long voyages must be carefully scrutinised before any general deductions are made from them. Similarly the varying conditions of wind and sea experienced in actual service introduce disturbances which it is not possible to appraise with any approach to accuracy; and on this ground trials in smooth water, calms, or light winds, and under circumstances which ensure the absence of influence of tides or currents, are alone of value for the purposes of exact comparisons between ship and ship.

Here we meet with an illustration of the general principle above laid down, viz., that sea-going experience is often a necessary corrective of smooth-water trials. Of two ships compared, one may be easier to drive on the smooth-water trial than the other, which, by reason of her greater length or different form, has the superior power of maintaining her speed in a heavy sea-way. But this admission only amounts to a

statement of the well-known fact that the form best suited for smooth-water propulsion is not always the best for sea-going purposes. In short, the determination of the form of a vessel is not governed by any abstract considerations of "least resistance;" but by the fulfilment of certain essential conditions, such as carrying-power, accommodation, speed, stability, and good sea-going qualities, and their association with the most shapely and easily-driven form which can be obtained under the circumstances.

If we neglect for the moment the influence of variations in efficiency of the propelling machinery and the propellers, then each measured mile speed-trial made under uniform conditions may be treated as a "model experiment," and from it may be inferred the probable performance of vessels similar in form, but differing in dimensions. If the fullest advantages are to be derived from such trials, then the trials should be made on the "progressive system," with which Mr. W. Denny's name has been so closely associated, and which is too well known to require any detailed description here. In order that an individual ship may be used as an exemplar over the greatest ranges of size and speed for ships of similar form, she must be tried at several speeds, from the lowest she can be well run at, up to the highest that her engines will drive her, when every exertion is being made in the stokehold. Critics of measured mile trials commonly dwell upon the folly of taking note of performances which will never be repeated in practice or over long periods of steaming. They do not sufficiently recognise the great value for *purposes of future designs* of "spots" on the curves of horse-power or co-efficients of performance, lying far beyond anything which the vessel will ordinarily reach. But designers of ships are better instructed, and are glad to have these experimental data, even if they have been obtained under wasteful conditions of coal-consumption, and by running the engines much faster than would be done on practice.

In passing, I may be permitted to give one word of caution. Cases not a few have come under my notice wherein estimates of the horse-power required in new ships have been based on the performances of *larger* ships of similar form, without any allowance being made for the "corresponding speeds" of the two ships—to quote a phrase which we owe, as well as the law of comparison it represents, to the late Mr.

Froude. This omission is often the source of grave errors, if there are considerable differences in the sizes of the ships compared, especially as higher speeds are attained or designed.

Turning to the other two elements of efficiency—that of the propelling machinery and that of the propellers—it will assist the discussion if we assume that a particular ship has applied to her, in succession, various types of engines, boilers, etc., and various propellers. Then her form, draught, and trim, and the condition of her wetted surface being kept constant, her performance will be affected only by changes in the propelling apparatus. I do not propose to say anything as to the influence upon economical propulsion which may be exercised by changes in the boilers, the steam-pressure, etc.—important though that influence may be. Confining attention to the efficiency of the engines considered as pieces of mechanism, in which certain amounts of mechanical work are developed, it must be admitted that there is a fruitful field for study in considering the manner in which the indicated horse-power is expended. In his address at the opening meeting the President of the Institution alluded to this branch of the subject, and called particular attention to certain trials recently made in the United States steamer "Albatross." Without attaching any great importance to the figures given for that particular vessel, it may be remarked that the method then used has long been established in the United States. My friend Mr. Isherwood, formerly Chief Engineer of the U.S. Navy, has had most to do with the introduction of this mode of analyzing steamship efficiency. Anyone who wishes to see one of the best examples of the system may turn with advantage to the Report of the Secretary of the U.S. Navy for 1875, wherein will be found details of trials made on a steam-launch by Mr. Isherwood. It would be out of place to reproduce these details now, but they are well worth study. Many of the experiments made with this launch could not be well repeated on a large ship; but they are instructive as indicating the various sources of loss, and the relative magnitudes of the losses on the constant friction of the engines, the friction of the load, the friction and waste-work of propellers, etc. On all these points we need more and better information than we now possess. Empirical rules, or rules founded on limited experiments, will not suffice. And in association with speed-trials, or as preludes to them, such experiments might be

advantageously made, at least on typical engines. Waste-work, in overcoming internal resistances, etc., there must be, no doubt; but every effort should be made to diminish its amount.

The late Mr. W. Froude, in his able writings on the subject of steamship propulsion, laid great stress on this part of the subject, and one of his latest inventions was the turbine-dynamometer which he made for the Admiralty, in order to determine the loss of power occurring between the cylinders and the propellers. Although, as yet, little information has been published respecting the results of trials with this instrument, it may be hoped that the Admiralty will eventually give to the professions the benefit of their experience, with that liberality which they have invariably shown hitherto in similar cases.

Although private firms are not in a position to rival the Admiralty in elaborate experimental apparatus, much information may be obtained by simple experiments. For instance, the screws may be disconnected and the engines run at various speeds in order to determine the waste-work of the unloaded mechanism. This was done in the course of the elaborate trials with the "Iris;" it has been done also in other swift vessels and torpedo boats. Besides the information thus obtained, running the engines unloaded constitutes a very good test of the satisfactory condition of the bearings, etc. In addition, it has often furnished explanations of the real causes of vibration in high-powered steamships, and disposed of some clever but not sound theories on the subject.

Another simple and valuable experiment, commonly made on ships of the Royal Navy when they are placed in dry dock, consists in the practical determination of the resistance to revolution offered by the bearings of the after pieces of shafting, when disconnected. The practice became general after some remarkable discoveries were made of the great losses incurred in a particular vessel owing to the undue tightness of the after bearings. I know of similar experiences having been gained in foreign war-ships: perhaps the same may hold good in some merchant steamers; at all events the trial is readily made.

It is difficult to exaggerate the value of measured mile trials as tests of the efficiency of propellers. In speaking thus, all kinds might be included; but for the present I would refer only to screw-propellers.

Most persons who have studied the mathematical theories of the action of screw-propellers have reached the conclusion that experiment alone can be trusted in the determination of the dimensions and forms of the screws suitable for a certain set of conditions. This becomes abundantly evident when one has to go beyond precedent, and to deal with higher speeds of ships and propellers than have been attempted previously. In the construction of torpedo boats the selection of the best screws has involved the carrying out of long and costly experiments. The discoveries made during the trials of H.M.S. "Iris" were nothing short of startling, showing as they did that by simply varying the screws—all other conditions remaining practically unchanged—the speed of the ship was increased from $16\frac{1}{2}$ to $18\frac{1}{2}$ knots per hour. More recent trials of very swift ships, with which I am conversant, have shown no less remarkable results. Nor is it reasonable to suppose that this possibility of improved performance by changes in screws holds good only for very swift ships. Cases have come to my knowledge where, through accidents to their screws, cargo steamers have been left with very seriously diminished blade area, and yet have performed well. Probably members may be able to refer to similar incidents in their own experience. These observations tend to throw doubts upon the ordinary assumption that the screws actually fitted to cargo steamers are the best possible screws. Anyone interested in such vessels, who makes the matter a subject of experiment, will probably be amply repaid for his trouble. When regard is had to the economies which have actually been obtained by means of speed-trials with various screws, and to the straining after economy in all directions, which has become essential under the present condition of the mercantile marine, it does appear desirable to devote greater attention to possible improvements in the screw-propellers of cargo steamers. And if I may venture one step further, I would suggest for consideration also the possible advantage of increasing the revolutions and piston speeds in such vessels. Savings in weight of machinery, if they can be made without decrease in strength and durability, must be advantageous, and may be so even if purchased at a greater first cost. Whether these views are accepted or not, it is undeniable that, if for no other reason, yet in connection with the selection of the best propellers for steamers, speed-trials have

ample justification. The full advantages are only to be obtained by means of the progressive system of trials, which furnishes evidence of the continued efficiency, or the decreased efficiency, of the screws under trial, as the speeds are increased.

Here also experience on actual service at sea is a valuable supplement to, but no substitute for, the trials made on the measured mile.

There are certain general rules essential to the proper conduct of measured mile trials; if these are disregarded the results are not to be depended upon. It is not necessary to do more than mention some of the most important. The *course* kept while running the mile should be exactly perpendicular to the sight-lines joining the two boundary posts at either end of the mile. If any other course is steered the distance run will be greater than the mile, and it is astonishing to find, especially in ships of very high speed, how small a departure from the prescribed course sensibly affects the speed. The best method of securing this result is to have buoys laid down, as is done on the Admiralty measured miles. It would be a great improvement to the Whitley mile if buoys were laid down, and it is probable that an entire change in the position of the mile to some position further to the North would be beneficial. This is a matter on which I cannot speak with any authority, but which deserves consideration.

All observations should be made with the greatest care and in a systematic manner. The influence of tide or current should be eliminated by means of consecutive runs in opposite directions. The ship should make a long sweep in turning, and have regained her speed (which will certainly be reduced in turning) before she re-enters the mile. A good depth of water should be ensured in relation to the draughts and speeds of the ships tried: for it is well known that relatively shallow water involves greater resistance and a loss of speed. The force and direction of the wind are also matters which should invariably be noted. As regards the engine-room and stokehold regulations I need say nothing.

In conclusion, I would again draw attention to the fact that the speed-trials of steamships require to be associated with resistance experiments on models of the ships, if the completest possible analysis of the results is to be attempted. And I would venture to suggest that it would be a great advantage to this district if there were

established an experimental establishment, on lines similar to that of the establishment created by the late Mr. Froude for the Admiralty, and still conducted by Mr. R. E. Froude. This suggestion is only a repetition of what I have repeatedly urged upon private shipbuilders. Knowing, as I do, the immense advantage which the Admiralty derive from the Torquay experimental establishment, I feel confident that the shipbuilders and engineers of the North-East Coast would gain greatly from the creation in our midst of a well-appointed establishment, conducted by a gentleman whose character and ability would command respect and trust. There is only one private firm in the country which yet possesses an establishment for making model experiments; but there can be no doubt that as higher and higher speeds have to be attained every possible means will have to be taken to secure success and economy, and the number of these establishments will be increased. To a single firm the expense is considerable, both for construction and maintenance: in a district in which shipbuilding is carried on upon so grand a scale the undertaking should present no difficulty. The North-East Coast is chiefly known for its work on cargo steamers of moderate speeds; but some of the swiftest vessels yet built have been produced here, and it may be hoped that still further advances will be made in the construction of such vessels. Moreover, there is good reason for believing that in certain classes, at least of cargo steamers, higher speeds than are now common might advantageously be adopted. Variations and improvements in the types of ships will continue to be introduced; there is no finality in our professional work, and each step in advance involves the solution of new problems. Experiment wedded to theory, and the exhaustive analysis of trial data are our best guides in advancing from the knowledge of the present to the achievements of the future.

Mr. F. C. Marshall, in rising to open the discussion, said, he agreed with Mr. White on the importance of having properly conducted speed-trials, and felt that Mr. White was doing good service in entering upon the subject. Trial trips had become almost a by-word on the North-East Coast, the luncheon forming the most prominent part of

the occasion, and the real business being hurried over as quickly as possible. With regard to the measured mile at Whitley, neither as to locality or arrangement could it be considered satisfactory, the greatest ignorance prevailed amongst those pilots and others usually in charge of vessels as to the correct course to be steered while running the distance; and it was nothing unusual to see vessels being tried two or even three points of the compass out of the true north, the proper course to be run for the true distance. Then again, it was frequently impossible to distinguish the inland posts, and therefore the adoption of accurately moored buoys, placed on the proper course, was of the utmost importance. Another most important point not mentioned by Mr. White, and almost entirely neglected in trial trips on this coast, even by the shipbuilders themselves, was the steering of the vessel so as to secure a straight course; the time and distance were seriously increased by the serpentine route frequently adopted, and the result rendered altogether worthless. This was specially the case in high speed vessels, where the difference of a few seconds involved issues of the utmost value. It was therefore not only necessary to have a measured distance conveniently situated and readily observed, but we should have well qualified and experienced men to guide the vessel. The author's remarks on the subject of propellers were most important and opportune. In no part of marine engineering were we so much "at sea," and obliged to adopt the empirical method, as in the designing of the propeller for any given vessel, especially if it happened to be one of a special or novel type, involving conditions out of the beaten track; and he quite agreed with Mr. White on the importance of having somewhere in their midst a tank for experimental purposes, where propeller trials could be made with models as was now done for ships at Dumbarton and Torquay. He might say that, with a view to the accomplishment of this, he had mentioned to the Principal of the College of Physical Science, the idea of introducing such a tank into the new college buildings, and that gentleman rose very warmly to the idea. He hoped the Council of the College would not be afraid of an additional expense of some £10,000 to effect that purpose. He should like also to see a proper house for testing materials, similar to those at work in University College, London; Nottingham College; Owen's College, Manchester; and in most large centres, except Newcastle.

Mr. Wm. Clark (Sunderland) thought nothing could have been more appropriate than the paper they had listened to, and, considering the authority from which it came, it ought to have great weight with shipowners and shipbuilders. He need hardly say that he spoke as an engineer, and they must all admit that they had been very much behindhand in the matter of securing reliable information as to the resistance of steamships, but he thought that the difficulties of bad weather with which they had to contend, the bad position of the measured mile, etc., in some measure accounted for this. Mr. White has referred to the speed curves of the H.M.S. "Iris," which show what a great improvement was made in the efficiency of the propeller of that vessel by reducing its surface. These curves clearly illustrate the great loss due to unnecessary surface on the propeller of a ship. Some years ago, impressed with the advisability of keeping the surface of propellers as small as possible, he fitted one of a considerably reduced area on a cargo boat. Probably nothing could have been more suitable for smooth water and at the loaded draft, but at the light draft and in head winds and seas it was found inefficient and was discarded for a propeller of increased surface. Owing, then, to the varying drafts of a cargo boat from extremely light, when travelling without a cargo, to one of great depth loaded, the area of the propeller is naturally a compromise; and we can therefore see at what a disadvantage a cargo boat is placed when running on the measured mile as compared to a vessel of nearly constant draft, and can understand why the speed of a cargo boat is generally increased by losing a portion of the surface of its propeller whilst prosecuting a voyage loaded. He might also mention for the benefit of the shipowners present that, from his experience, at a given draft, and with the same number of revolutions, the average speed of a vessel on the voyage is greater than on the measured mile.

Mr. Coote said, he believed one of the difficulties with regard to trial trips had been, to use a French phrase, that of "*mal de mer*." He thought there was a great deal in the fact that they had not a sufficiently smooth and safe course for speed-trials, and he was rather of opinion that they would never be able to carry out in a regular manner, on the present course, the trials Mr. White had suggested. They in this district prided themselves on the cargo carrier, and he

thought they had produced the best type of that vessel in the world. Although here they had not made progressive trials, as had been done by some firms on the Clyde, yet the Clyde builders acknowledged that they could not compete with our district for this class of vessel. He thought that one reason for not having these trials with the ordinary carrying steamer of nine or ten knots was the uniformity of the type. There would be no particular difference, however many scientific trials might be made. He thought the paper read was an interesting one, and hoped that it would do much to improve a future type of vessel which they might some day build.

Mr. B. G. NICHOL enlarged upon the necessity of a complete and thorough understanding between the engineers and the shipbuilders, in order that ample data should be furnished by each, to enable the other to predict definitely the speed of any vessel at sea. In his experience he had found very few cases in which such data was supplied, and approximate results were all that could be relied on. He hoped, however, that one of the great benefits resulting from this Institution would be that engineers and shipbuilders would realize that they served their own interests and the interests of the North-East Coast best by each member diffusing among the others all the results which his ability or experience has enabled him to acquire.

Mr. TREWENT said, that as far as he knew shipbuilders were always willing to give all the information in their power. The last two ships their firm laid down they specially asked the engineers to look at the models and give their opinion. Shipbuilders had often great difficulty in getting from the engineers reliable data of trial trips. He knew of one case where, in giving a quotation for engines, the engineers refused to give the diameter of the cylinders; they, the shipbuilders, being told that a certain horse-power was guaranteed and they must be content with getting that horse-power. The great difficulty in the trial trips on the North-East Coast arose through delays, such as going down the river to suit the tide, adjusting compasses, taking on board the visitors, etc., which consumed such an amount of time, that after having three or four runs on the measured mile it was time to save the tide back to dock. He thought that with such an Institution as they had now got they might appoint a paid professional man, who would attend all trial trips, and the members of the Institution would thus get good reliable data.

His opinion was that in all their ordinary cargo boats they were quite wrong in their design. The midship area might be greatly increased, and the entrance and run fined down, keeping the displacement the same, or even larger, with less resistance than with the usual proportions of beam to length. If after the design for a cargo steamer had been prepared it was desired to make her carry 100 or 200 tons more the boat was generally lengthened, whereas he thought the beam of the vessel might be increased amidships, doing away with the long flat side, making the water lines a fair curve from stem to stern, but Lloyd's stepped in and by their rules prevented this from being done without a great increase of scantling. He regretted that as time was limited he was unable to say what he intended on the very valuable paper Mr. White had read, and to which they had listened with so much interest.

Mr. MAVOR said on the Clyde the trials generally took two days, and thought that if they wished to compete with the Clyde in this matter they also must take more time with their trials. He dwelt upon the advisability of getting more information from the captains and engineers of new ships, that builders might form a more reliable estimate of work at sea under all conditions of weather, loading, etc. As long ago as 1868 a very complete set of observations of performance at sea was made by Mr. W. C. Bergius, who went across the Atlantic in the S.S. "Westphalia." A report of these observations will be found in the *Engineer* for 1868 or 1869, and is a model of care and exactitude. One very important part of the question had not been touched upon, viz., the part relating to the vibration of steamships, the first published information on that subject having only been printed this year.

Mr. HECK desired to bring the discussion back to what he considered the most important element in the paper, viz., the suggestion of making an experimental tank. Such a tank would be of great value in determining the speed of ships and the efficiency of propellers, and would also assist us in the solution of the problem of the resistance of bodies moving in fluids, a problem which had baffled even Newton, and which could only be brought within the grasp and power of mathematical analysis by the aid of experiments. In reference to speed-trials, he was afraid that the expense attending them had some-

thing to do with their absence on this coast. He hoped, however, that the suggestions would not be allowed to drop, as their adoption would improve the tone and character of East Coast shipbuilding. At the present time he would prefer to give orders for large passenger vessels to the Clyde, from such a firm, for instance, as Denny Brothers, in consequence of the completeness with which all the details were worked out. In reference to the remarks made by one of the speakers, he would like to point out that the nature and the amount of the strains which vessels experienced was not yet thoroughly understood, and therefore mathematical nicety in determining the scantling was impossible. Lloyds' rules had therefore been framed on sound experience, and after consultation had been made with nearly all the shipbuilding firms.

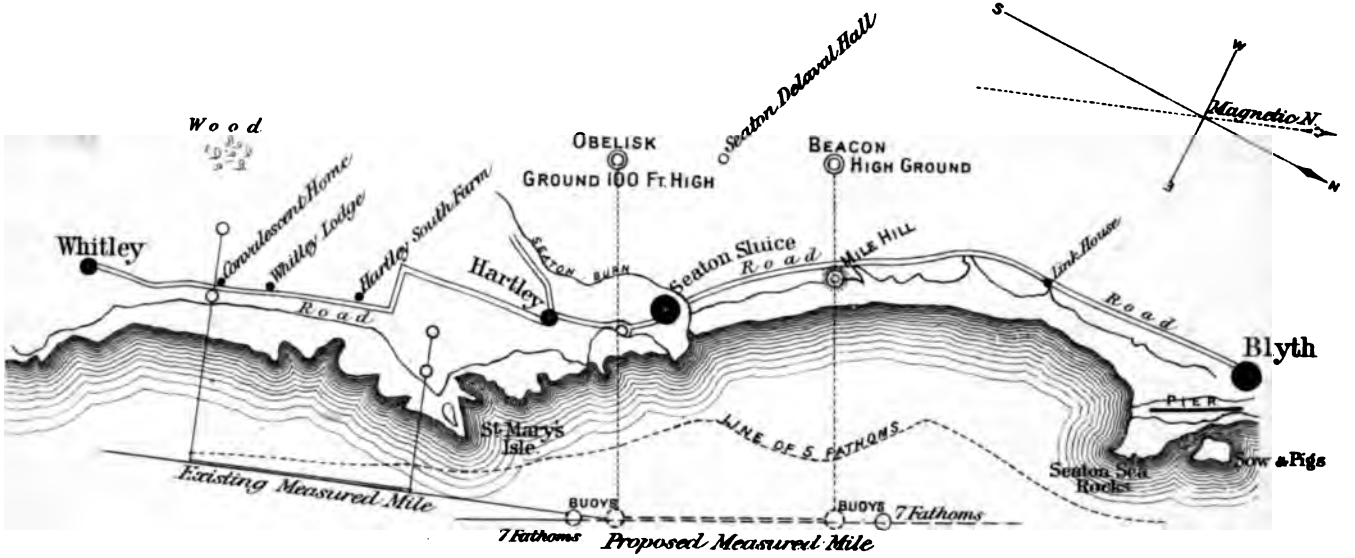
Mr. WIGHAM RICHARDSON said the Institution ought to be happy in having a paper from such an authority as Mr. White. It might be interesting to the members to know how it was that the measured mile was placed in its present position. When the former posts were carried away and there was no proper measured mile, some of his friends suggested that he should take the matter up and arrange for posts to be fixed. The question then arose where to put the posts, and he must confess they had placed them in a very bad position, but the desire was to have the course as near the mouth of the Tyne as possible, and they had the greatest trouble with the owners of the land, who were approached through the solicitors of his firm. One of the landowners said he would knock the posts down again as soon as they were put up. Permission was, however, at last got, and the posts placed in their present position. It had been intended to put down buoys, but this was abandoned owing to objections raised by fishermen and others. He also said that the greatest objection to the present position was, that owing to the currents, the speed got was often not the true speed, and instanced the case of a steamer, the engines of which had been built by his firm, which actually ran a less speed on the measured mile than she could at sea under ordinary circumstances. The new site proposed was very much better, and he should like to ask Mr. White whether he did not think it would be advisable to put two sets of posts in positions, so that a steamer could, if required, run, say sixty revolutions on one course and fifty on the other?

The PRESIDENT said he had long held that the measured mile was in a very bad position, and he had mentioned to Mr. Richardson that something should be done to improve its position.

Mr. WHITE, in replying, said that the type of vessel built in this district was so little varied that one trial would often suffice for a great many ships. He hoped that the discussion which had taken place would lead to their having a better measured mile, and that they would take up the matter of the experimental tank for ship models; he felt quite confident that the one without the other would not be sufficient. He thought Mr. Coote had rather over-estimated the excellence of their present type of vessel; he quite concurred that it was wonderful that so little power should drive such a huge structure through the water at such a speed, but if they had got a success it was no reason why they should not improve. In conclusion he desired to express his thanks to Mr. D. F. Black, of Elswick shipyard, and Mr. Shereton Holmes, civil engineer, for the trouble they had taken in supplying information as regards the present site of the measured mile, and that of the proposed new one.

The PRESIDENT proposed a vote of thanks to Mr. White for his paper.

WHITLEY MEASURED MILE COURSE.



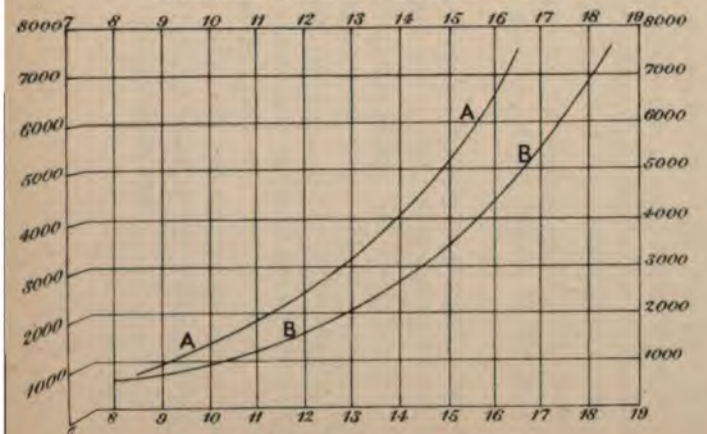
CURVE A—

Screw, 4 Blades	18′ 6½″ Diameter.
Mean Pitch	18′ 2″ „
Blade Area	194 Square Feet.

CURVE B—

Screw, 4 Blades	16′ 3½″ Diameter.
Pitch	19′ 11½″ „
Blade Area	144 Square Feet.

H.M. DESPATCH VESSEL IRIS.



Scale of speed of Ship in Knots per Hour

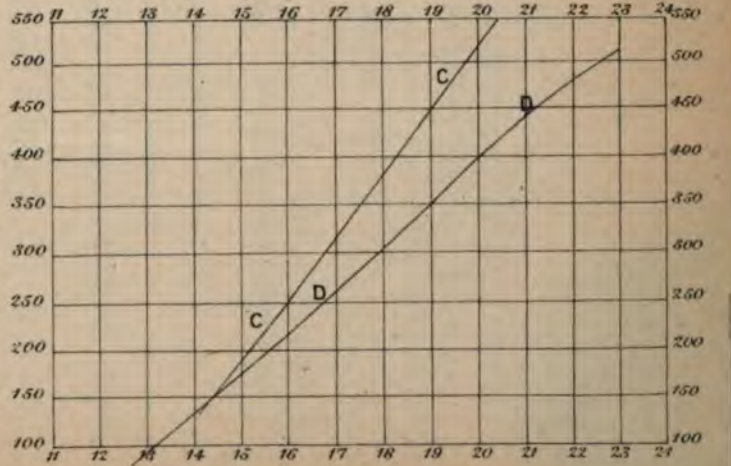
CURVE C—

Screw, 2 Blades	5′ 6″ Diameter.
Pitch	4′ 6″ „
Blade Area	496 Square Inches.

CURVE D—

Screw, 2 Blades	4′ 4″ Diameter.
Pitch	5′ 0″ „
Blade Area	540 Square Inches.

FIRST CLASS TORPEDO BOAT.



Scale of Indicated Horse Power

Scale of speed of Boat in Knots per Hour.

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.

FIRST SESSION, 1884–85.

GENERAL MEETING IN THE LECTURE HALL OF THE SUBSCRIPTION LIBRARY, SUNDERLAND, MONDAY, 26TH JANUARY, 1885.

W. BOYD, ESQ., PRESIDENT, IN THE CHAIR.

ON THE FORGING OF CRANK SHAFTS IN IRON AND STEEL.

BY HENRY FOWNES.

WHILE introducing this subject to your notice, which refers more particularly to crank shafts for marine engines, most of you will doubtless agree in calling the crank shaft one of the vital parts of the marine engine, and decidedly well worthy of some consideration by an Institution such as the "North-East Coast Institution of Engineers and Shipbuilders;" and in making these few practical remarks, those who are well versed in the subject will at once perceive that there is no originality about them whatever, which, indeed, is not for one moment claimed.

Nevertheless there will be many, particularly the younger members, before whom this information has perhaps never been presented in the graphic manner adopted in this paper; and when they see how crank shafts are made, or rather how, in the writer's opinion, they ought to be made, they will be better able to judge whether the flaws or marks which come under their notice in the course of their experience are of serious moment or not.

With this introduction, let us now go straight to our subject, dealing first of all with crank shafts made of iron, whether scrap iron or specially rolled iron which is sometimes used.

Kindly, however, for a few minutes give your attention while it is briefly drawn to the preliminary process; and, curiously enough, the first thing we usually require in making iron shafts is a piece of wood, the wood referred to being called a *ball bottom*, which varies in size according to the practice adopted at different works, size of furnaces, etc.

The scrap iron is first carefully selected, particularly for crank shafts, and at the works with which the writer is connected, viz., the Tyne Forge Company, Limited, very particular attention is paid to this matter.

A ball of scrap iron properly piled, with scrap all cleaned and scoured, together with perhaps four or five others (according to the size of the furnace) are placed in the ball furnace by means of a tool called a "peel" or "slice." This is greased on the top surface to allow of its being easily withdrawn from under the ball when in the furnace.

These balls having been in the furnace a sufficient time to bring them to a proper welding heat, will be found to be all stuck together, so that they can be easily withdrawn by a large pair of tongs called "shingling tongs." They are then placed under the hammer singly, and thoroughly welded together or shingled, and all the cinder and other impurities thoroughly hammered out. After this process they become shingled blooms, and these blooms are put into the furnace a second time, two or three together, in accordance with the size of slab required, and after hammering and thoroughly welding together they become slabs. For certain parts of crank shafts, which you will see shortly, either the sides or the ends of these slabs have to be thinned down by sets under the hammer, or in other words scarfed down.

So much for the preliminary process. As at all large forges a stock of these blooms and slabs is usually kept on hand, the process already described does not prevent the forgeman from proceeding with the next course at once, which is to pick up his staff or porter and pile on the end of it perhaps four slabs to commence with, as a start to lay up the web of the crank; the number of slabs being varied perhaps in accordance with the size of the hammer or the size of the furnace. This is clearly shown in Fig. 1; but it should be mentioned that these first slabs do little else than mend the porter.

You will observe in the diagram that there are spaces between the slabs, to make these, punchings are perhaps the handiest pieces of iron to use (if large enough); but not only in crank shafts but in

all other forgings built up of scrap iron or other slabs, want of attention to this little detail is the cause of many defective welds, indeed too much attention cannot be called to this little matter. These spaces are to allow the flames to play freely through them between the slabs, so that the centres of the flat surfaces of the slabs may come to as good a welding heat as the outside edges.

The end of the porter having been mended and made round, the lump on the end is drawn out to something like the shape shown by the dotted lines in Fig. 2. The top side of this lump is somewhat flattened to receive about four slabs, as shown on Fig. 3. After one side is made sound the heat is turned over, and exactly the same process repeated on the other side; and this is repeated by laying on slabs, alternately on each side, until the forgeman gets sufficient sound iron together to form the lump, or the butt, which he considers necessary to commence forming the crank web. This butt is generally left longer than the finished size of the crank web, and, of course, much thicker. Now, this lump or butt, as shown on Fig. 4, has an equal amount of iron on each side of the porter at the parts marked A and B; and, before proceeding to form the web, it is necessary that the porter should be well off to one side, as shown by Figs. 5 and 6. This is done by a process called bolting, or setting down, and the shaded part in Fig 5 is bolted or set down, which brings the porter right off to one side, as shown on Fig. 6. The shaded part having been rounded up into the porter somewhat elongates it, and one of the advantages of this is that the scarf ends of the ends of the slabs, marked D in Fig. 3, are either worked up out of the shaft altogether, into the porter, or, at any rate, if in the shaft at all, are in the heart of the collar, where they can do little harm.

The forgeman having now set his porter through, and made his butt sound, proceeds to set it down or taper it out towards that part of the web where the pin will be, preparatory to laying on his side slabs, as shown in Fig. 7. These slabs, which are broad and thin, should, if possible, be quite as long as the web the forgeman is laying up, so as to avoid scarfs in the length of the web, the bottom edges, however, being scarfed, as explained before. In the first instance, these side slabs are laid only on one side of the butt, but after these are heated and welded on, a similar number are put on the other side, after its having been turned over. This process of laying on the side slabs on alternate sides

of the heat, with the edges scarfed down, so that each slab may be perfectly welded or connected to the other, is continued until the forgeman gets enough iron together, in his judgment, to form rather bigger than the size of crank web required; and the lines on Fig. 8 show the direction in which the grain of the iron will run, the dotted circle being the crank pin. The forgeman then proceeds, by repeated heatings, to make sure of the whole mass being perfectly sound and solid; and the whole piece, which is much longer than the length of web required, is flattened down to a thickness something greater than the thickness eventually required, to allow for waste during heating in the furnace, and other causes.

The next process is to round up the crowns of the web, and the forging is now something near the size of the web required, as regards depth and thickness, but, as before mentioned, considerably longer. He now picks up a tool, usually made of steel, called a cutter, and with it cuts out one end of the web, being that nearest to the porter, as shown on Fig. 9. This done, he cuts out the triangular piece, shown on Fig. 10, which forms the other end of the web, or that farthest from the porter. In a small sized crank, provided the hammer is large enough, this is sometimes done in one heat, but, in a crank of moderate dimensions, it usually takes two heats. This is explained by the same Fig. 10, and, as shown, the pointed piece left sticking up is hammered down and drawn out to form the rounded part of the shaft as dotted; the end of this rounded part may then be scarfed down and slabs laid on, as shown in Fig. 11, to make the shaft out to the desired length. In the opinion of the writer, it is much better for crank shafts to be made under large sized hammers, beneath which you can get a sufficient body of iron laid up at once before cutting out, and the piece for the web sufficiently long, so as to avoid the patching required to make a good end, before laying on for finishing the crank. Indeed, in half crank shafts of a moderate size, it is better to avoid scarf ends altogether, by laying up sufficient iron at once to avoid laying on any more slabs, and this advantage will be obvious to you.

The forgeman having rounded up the neck of the crank, leaves a large lump, or swell, on the end, to form not only a base for the collar and the radius inside the collar, but also to make provision for the forging being somewhat longer, for the reasons which are about to be explained. Fig. 12 shows the base herewith mentioned. He next

proceeds to weld on one half of the collar, but it should be mentioned here that the collar slabs have been previously carefully made, bent to the radius required, and scarfed. They are, of course, made a good deal thicker than the finished size of the collar, to allow for cutting out. They are, however, put on as described in Fig. 13, where the dotted and shaded part shows the barrel of the shaft.

After having partially welded on one half of the collar, the forgeman turns the shaft over, and welds on the other half; which being done, and reheated, he makes the whole collar perfectly sound and circular, by continually turning the shaft round at a welding heat while under the hammer. He now has the collar made much thicker than he requires; but as it is necessary to turn the shaft end for end to finish the end next the porter, he must have something to balance it with, and work or handle it by, so he has to draw off a porter from the end of the collar, as shown by the dotted lines in Fig. 14. He next proceeds to mark off the collar from his sketch, and begins by cutting the inside edge of the same, as shown by the shaded parts in Fig. 15. He then marks off the outside of the collar, and nicks it down with a cutter, as shown in Fig. 15, in order that it may the more easily be cut off after the forging is finished, but leaving sufficient metal in the centre to hold it by, while finishing the other end. One half, or perhaps better than the half, of the crank shaft forging may now be said to be complete, and it is now turned end for end, and the original porter put through the furnace for the purpose of being cut off. After this has been done, if a collar is required at this end he proceeds to weld one on, in exactly the same manner as previously described, with the exception that he cuts the outside of the collar square down, and we have the forging as shown in Fig. 16.

The porter drawn on end of the first collar for the convenience of handling is now cut off, and the forging of the half crank shaft may be said to be complete. The process herewith described may, of course, be subject to slight modifications as required by circumstances, but, in the main, is the one adopted at the works with which the writer is connected; and, apart from being approved of by Lloyds, is perhaps the best and safest way calculated to produce sound and strong forgings for ordinary sized crank shafts.

Notwithstanding, however, the most careful supervision, and from

causes entirely beyond the manufacturers' control, such as carelessness, drink, etc., longitudinal marks sometimes show themselves in the pins, and up the insides of webs of crank shafts. Here refer to Fig. 8, which will explain more clearly these marks with which many of you are no doubt familiar. Now, should the finishing of the shaft not have proceeded too far before these marks are discovered, the writer is strongly in favour of placing the forging in the smith's hands (he must be a good smith or a good heater, by the way) to have these marks opened out, and the dirt, slag, or other impurities taken out, and the iron then thoroughly welded up again. This is best done when the crank pin is roughed up to within say a $\frac{1}{4}$-inch of the finished size. It is not meant to be said that a rank bad forging or a thoroughly bad weld can be got rid of in this manner, but many of the minor longitudinal marks, if discovered in time, can certainly be mended; and, candidly speaking, after having seen a crank pin thus treated, and examined it carefully, and tested it when heated all over, the writer would have much greater confidence in guaranteeing that shaft, than one which had not been similarly treated. Yet engineers have been known who would condemn a crank shaft altogether at the bare idea of its going near the smiths' fire, without taking the trouble to enquire whether the feature was good or bad.

Other ways of building up crank shafts, or rather crank webs, have been in vogue until quite recently, and may indeed yet be practised, although decidedly objectionable.

I will not trespass upon your time much further with reference to iron shafts, except to show you another method of building up crank shafts, which will only take a few seconds, and which probably is about the worst plan that could be adopted; and although it may be one of the worst plans, it is probably the quickest way of forging a crank web, and has, therefore, been adopted by some forgemen from perhaps lack of thought, and by others as the readiest way of turning out quantity without reference to quality. The writer has often discussed this question with forgemen, and good men too, not only with reference to crank shafts, but to other forgings also, and many of them have been most difficult to convince, their argument always being, "What does it matter, so long as it is soond" (to use the vernacular). Fig No. 17 will explain what is meant, where the black lines show the way the slabs are laid on, as against the other way which is dotted; but if

there is any virtue in the idea of fibre in iron at all, then the thing speaks for itself. There is also another reason why this plan is objectionable, *i.e.*, an imperfect weld might occur in that part of the crank shaft where perhaps the greatest stress is (the middle of the web), as shown by the lines on Fig. 17; and certainly by adopting the plan first described, the same amount of risk is avoided.

A great deal more might of course be said on the forging of iron crank shafts, but without wearying you further, we will now pass on to the few remarks still to be made on the forging of crank shafts in steel.

Scrap Steel.

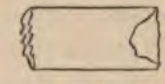
In crank shaft forgings made out of scrap steel the identical process described for scrap iron is usually adopted; but, in the writer's opinion, if steel for crank shafts is to be used at all, those forgings made from the steel ingot are much to be preferred.

This opinion is not hazarded without what may be considered sufficient reason, but to fully explain those reasons would take a considerable time, and would require the results of an exhaustive series of tests, all of which would hardly come under the province of this paper; in fact, the subject, in good hands, would probably afford sufficient matter for a paper by itself, dealing more exclusively with the "*material*" out of which crank shafts may be made. I may mention, though, that the tests I have myself seen made from forgings of scrap steel have been unusually bad, probably for the same reason as suggested by Mr. John, in his paper read before the Iron and Steel Institute in May, 1884. (See Journal of that Institute, No. 1, 1884, p. 145.)

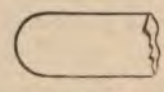
Ingot Steel.

In forging crank shafts out of steel ingots a hammer of very much greater power is required than that necessary for forging scrap iron. That is to say, to make a forging weighing one ton out of the steel ingot requires a very much heavier and larger hammer than to make the same forging weighing one ton out of scrap iron. In fact it may be said that the conditions are exactly reversed; for whereas in using scrap iron you build on slab after slab, and thus arrive (so to speak) at your greatest weight when the forging is finished, in forging steel out of the ingot you have to deal with your heaviest weight at the first

onset. Taking, for example, the steel crank shaft, the different phases in the forgings of which will now be shown to you. The steel ingot when first picked up by the forgemen weighs over 10 tons, the finished crank shaft forging when leaving the hammer only weighs $5\frac{1}{2}$ tons. Apart from that you have to deal with a solid mass of much denser material, requiring a very much greater power to produce any effect whatever upon the heart of the ingot. This question of the weight of the hammer is one that should not be lost sight of by those ordering crank shafts forged out of the solid steel ingot, and it is also a question upon which there is considerable difference of opinion among manufacturers themselves. The writer may here mention a fact which has come under his own notice with reference to this matter. In forging a large ingot, which perhaps may possibly be somewhat above the power of the hammer, the outside surface of the metal draws first, forming a cavity in the centre of the end of the ingot thus—



But when the same forging was reduced in size so as to be within the power of the hammer, the centre of the end of the ingot apparently swelled out thus—



In forging crank shafts out of the steel ingot considerable judgment is required on the part of the forgeman, much more so than in forging scrap iron. For instance, in forging with scrap iron, should the forgeman find himself rather short of material he can probably easily lay on more slabs, but such a thing in forging out of the steel ingot is impracticable; and if he has miscalculated his material and finds he has not sufficient material to complete his job, the ingot is spoiled or lost. As the top of the cast steel ingot has the greatest chance of being unsound, it is necessary that the forgeman should calculate his material so as to make as much of his forging as possible out of the bottom or soundest part of the ingot, the top ends of the ingots being usually piped, and more or less full of air holes. The forgeman picks up the ingot my means of a porter and clamps similar to that shown in Fig. 18, or some other arrangement equally efficient

adopted by different manufacturers. He then proceeds to draw away the tang end, as it is called, out of the top part of the ingot, which has the greatest chance of being unsound; and, theoretically speaking, should only leave as much of the ingot to work upon as will exactly enable him to complete the forging he has to make. Having drawn away the tang end, as shown in Fig. 19, he turns his ingot end for end, and secures it by a porter similar to that shown in Fig. 20, or some method which may serve the purpose equally well. He then proceeds to hammer out the centre part of the ingot to something near the thickness of the webs, as shown in Fig. 21, the dotted lines showing the original form of the ingot. He next cuts out the piece between the two webs, as shown in Fig. 22, leaving just as much material in the part marked E, that when rounded up to the size required it will draw out exactly to the length wanted between the two webs. It may here be remarked that the example adopted is what is commonly termed a double throw crank, as being a more interesting illustration. The middle part having been rounded up to the size required, and drawn out to the proper length, is twisted so as to bring the two crank webs at right angles; this is explained by Fig. 23. He now cuts out the two triangular pieces shown dotted on Fig. 24, forming the outer end of one crank web. Then by means of some manipulation with sets and cutters the end of the piece is set down to form the collar, which is fully explained by Figs. 25 and 26; which manipulation, it should be observed, does not in any way distort the material by undue stress. The part NO marked on Fig. 25 is then drawn or hammered down to the diameter required; and if there is any surplus material, which, theoretically speaking, there should not be, it is cut off the end of the collar at A, as shown on Fig. 26. One end of the shaft forging may now be said to be complete, and it is turned end for end, and, for a shaft of similar design, has to be handled by a porter, the same as that shown on Fig. 27. He then cuts out the figures dotted on Fig. 27, and finishes a collar on this end in exactly the same way as the first collar was formed. The original tang end, or porter, drawn out of the top of the ingot, as shown on Fig. 28, is then cut off, and the forging may be said to be complete.

The writer does not mean to say that the ingot in question is the best shape that could possibly be got for the job; but, at the same time, it may be regarded as a fairly representative one.

The idea of getting up a large mass of iron and hammering the job out of the solid lump, as in steel, might, with advantage perhaps, be more generally practised, thus much of the risk of scarf ends would be avoided. Pretty much the same remarks as to the weight of hammer apply in this case to iron as to steel. In proof of this, it has recently been shown that the scarf weld of a stern frame, if above a certain section, cannot be welded solid by hand hammers; but to make a sound weld requires a steam hammer (which is probably the handiest) or some other means of producing the necessary power.

The writer, in his remarks, has endeavoured not to cry down iron, as doubtless its day is not yet done, and for a long time it will certainly hold its own for many uses—as long for crank shafts as perhaps anything else. In conclusion, he trusts that these "few practical remarks" will have given the members a faint idea of the difference between forging crank shafts in iron and in steel.

Mr. Luke Hope inquired whether it would not be better to forge the steel crank shaft out of a square ingot, and so avoid the twisting required to bring the cranks at right angles, as in Fig. 23.

Mr. C. W. Hutchinson, in commenting on the neat arrangement of the paper, said it was clear and to the point. The writer had wisely avoided the notion that everybody knew as much about the subject as he did himself; and he (Mr. Hutchinson) considered that when anyone wanted to convey information and knowledge the best way to do so was to make everything simple and pointed. In referring to the flaws found in the steel shafts, he said, Whitworth, Krupp, and others, drill a hole through the centre of the shaft, not merely to cut out the "piping" or longitudinal porous flaw, but to remove the veins or ramifications of the flaw, since these, in the elastic working of the material, spread further and further through it towards serious development. The bore-hole therefore not only removes the unsound material, but takes away the incipient beginnings of fracture. Mr. Hutchinson regretted that the writer of the paper had not followed the processes of a double throw crank in wrought iron as well as in steel.

Mr. Jacob Wallau said that it was important to thoroughly clean the scrap before using it, and he would like to know what system of cleaning Mr. Fownes recommended. He would also like

to have Mr. Fownes' opinion as to what size or weight of hammer was required for any particular size of shaft. He quite agreed that twisting of crank shafts was not desirable either in iron or steel. Drilling seemed to him to be, in many cases, undesirable in iron as well as in steel, for drilling a hole into a shaft certainly did not make it stronger, and the working of the cracks was, in his opinion, often only a supposition and not a reality, and in that case drilling was useless.

Mr. ARTHUR LAING inquired if it would not be better to use a V anvil block and a V head in forging shafts, and thus the iron would be better worked through to the centre than when hammered between the ordinary flat faces of the hammer and anvil block.

Mr. FOLEY said, as far as his experience had gone, laying on two welding segments to form the coupling, as in Fig. 13, did not insure a sound job. It seemed to him the extent of the weld circumferentially was too great, and that three or four segments should be used instead of two. He would be glad to know what Mr. Fownes' opinion was on this point.

Mr. NICHOL expressed himself exceedingly pleased with the instructive and graphic manner in which Mr. Fownes had expounded to them the various methods adopted in the manufacture of crank shafts. He (Mr. Nichol) had seen many cranks made on the system first described, and illustrated in Fig. 7; but it was the first time he had heard of crank shafts being made according to the second plan, shown by Fig. 17. He wished to call particular attention to a question asked by Mr. Luke Hope, and trusted Mr. Fownes, in his reply, would state his opinion as to the relative merits of two double throw steel crank shafts; in the one case where in process of manufacture the shaft is twisted through an angle of 90 degrees between the cranks, and in the other case where the shaft is made from a square ingot. He considered that therein might lie the true explanation of some fractured crank shafts. He had heard it stated, on good authority, that in many steel mills in this country, steel crank shafts had been fitted, removed, and replaced by iron shafts. Referring to "flaws," he said that sometimes small fragments of brick, lime, or other matter got between the slabs and produced longitudinal opening or fracture, but very few engineers would condemn a shaft for fracture of this kind. He was pleased to hear that the firm with which Mr. Fownes

was connected had adopted a method of welding up flaws of this nature. Fracture most frequently occurs in the fillets round the crank pin or where the shaft joins the web, and when this takes place the shaft should be at once replaced.

Mr. ALEXANDER TAYLOR inquired whether there would not be a greater stress set up in the material owing to the treatment it received in setting down the end portion of the shaft close to the crank web, as shown in Fig. 24, than could possibly take place in twisting the cranks to right angles, when we remember the twisting is distributed over a length of at least two feet.

Mr. D. MYLES asked if hydraulic pressure could not be applied in the forging of crank shafts?

The PRESIDENT thought that the diagrams, and the mode in which Mr. Fownes had prepared his paper, constituted a striking example of the benefit which a society like theirs would confer on the district. He had been a member for some years of the Institution of Mechanical Engineers, and he could say without hesitation that he had never heard a particular point in manufacturing practice more clearly expounded than in the paper they had just listened to. Some years ago he had a little experience in making forgings, and he was bound to say that he did not find his experience quite tally with that of Mr. Fownes. With regard to the relationship that existed between the hammer and the forging, he said that the hammer might be a heavy one in one case and a light one in another. It had always appeared to him that the stroke of the hammer was an important element to be taken into consideration. They all knew that the hammer had a much greater momentum at the end of a 3-feet stroke than at the end of a 2-feet stroke. Another case in which a long stroke had a better effect was in the rounding over of the crank, as shown in Figs. 10 and 11. His experience was, that throughout the whole of the forging the stroke of the hammer was a very important element to be taken into consideration. Those who had had any experience with the iron shaft would know the difficulties they had to contend with on account of the lines, marks, and other flaws so often found to exist in the forging. They had nothing of that in the steel shaft; and he thought that the steel shaft, when put into proper hands, was a much more reliable piece of workmanship than any iron shaft, however well it might be laid up.

Mr. JOHN THOMPSON took exception to the assumption of the previous speaker that the steel ingot was perfection. In many cases there were air-holes and other similar imperfections in steel ingots, and as the ingot when worked under the hammer is not at a welding heat, these holes although they may be hammered close are still not made sound. With regard to twisting, he considered that if there was a moderate distance between the jaws of a crank it could do no harm to twist it to a right angle; but if the distance was very short, a forgeman, for his own sake, would not twist it, because he would not have space enough between the jaws to hammer the part disorted by twisting. As to the effect of forging with too light a hammer, he advised his hearers to try an experiment for themselves; he suggested that they should take a piece of cast lead, say an inch square in section, and they would find that by lightly hammering it to a round section a hole would be found right through it; and just in the same way they could take a steel ingot and hammer it from square to round, and if the hammer was not a very heavy one to strike through to the centre, they would have the same result. The great thing was to have a heavy hammer, one that would strike to the centre. He could not tell them what weight of hammer was required for a certain sized forging, but he advised them to have a hammer that would do the required work with the least number of blows, and they would then get the soundest material and the cheapest work. Whether making iron or steel shafts he considered the use of light hammers altogether a mistake. It had been suggested that crank shafts should be pressed, but he should like some member of the Institution to tell him what hydraulic pressure would be necessary to make a crank shaft like the one shown on the diagrams before them; in his opinion, no machine that they had at the present day could make such a shaft. He had no doubt that the steel crank shaft would at some future time be *the* shaft, but at present it was not so reliable as a shaft of good wrought iron made up bit by bit, and every piece of which could be answered for.

Mr. LEWIS entirely disagreed with some of the remarks of the previous speaker. He (Mr. Lewis) had had some experience with steel, and he could state that 90 degrees was only an ordinary angle of twist for steel of the requisite quality when at a bright red heat, whereas, owing to the layers out of which an iron shaft is built

up in forging, the danger of injuring the shaft in twisting is very great. He had seen a shaft in an ocean "liner" after the vessel had a sharp race against time, where, close to the crank web, the outside of the shaft showed the outlines of many of the different pieces out of which it was composed. The shaft was not bad, and it worked for a considerable time after he saw it; but if such a thing had been observed in a steel shaft, the shaft would have been condemned at once. He considered that the hammering which a shaft underwent caused a far greater stress in it than did twisting. One great advantage in the steel shaft (apart from that portion which had the pipe in it, and which every forgeman would try to get rid of) was that the heat in the furnace struck on the outside only, and comparatively affected the steel shaft to a much less degree than it did an iron shaft. The quality of the coal used in the furnaces varied considerably, and they all knew that even the best coal was not free from sulphur; and the numerous slabs from which an iron shaft was built being entirely surrounded with flame in the furnace, however well a shaft was hammered, the cinder could not be entirely removed, but showed itself at various places. In steel shafts, where the heat only played on the outside, they had nothing of that; besides, steel ingots were always worked in gas furnaces. As far as he (Mr. Lewis) remembered, there were many vessels that had not got clear certificates for their wrought iron crank shafts, and that, he considered, showed that a great many wrought iron crank shafts were faulty; but just because the material from which they were made was known to be good the shafts were allowed to be used. The cast steel crank shaft was superior to the forged steel crank shaft, as there was no severe treatment put upon the material, and all strains could be avoided, and the material could be made to answer every test that could be required by Lloyds' and other inspectors. He knew from experience that two shafts of that material, and 13-in. diameter, had been running for twelve months, and a locomotive shaft had been running five years on the North-British Railway, so they would see that cast steel shafts had proved themselves to stand thoroughly; and, in his opinion, they were preferable to forged steel, but he considered forged steel to be three or four hundred per cent better than wrought iron for crank shafts.

Mr. PUTNAM said, he rather thought Mr. Fownes had missed a point in not touching upon built cranks. In built cranks they could

put a great amount of work upon the pin, and at the same time be certain that it was sound, whereas in the case of a solid crank the pin was simply a spongy mass. One gentleman had asked if it was a fact that some steel makers had been supplied with iron cranks. He could assure him that it had been so, for the firm with which he was connected (the Darlington Forge Company) had supplied six of the largest steel makers in this country with wrought iron cranks, and several of them were to replace steel ones. He certainly thought that steel makers ought by this time to know what was best for them. The previous speaker had mentioned steel locomotive cranks, and compared them very favourably with iron ones. Perhaps it would interest them to know that two of the leading railway companies were giving up the use of steel cranks, and returning to iron ones. He might also state that the Board of Trade returns, extending over a period of ten years, from 1873 to 1883, gave an average mileage in favour of iron over steel of 10,000 miles per crank. When the fact that iron cranks were lasting longer than steel cranks was brought under the notice of steel makers, some eight years ago, they said, "Wait a short time; steel is still in its infancy;" but although a considerable time had elapsed since then, he found that the last Board of Trade returns for 1884 gave the average mileage per crank in favour of iron as 60,000 miles. with regard to the same gentleman's remarks upon the inferior quality of coal used by forge masters, any forge master would tell them that only the best coal would do, for the simple reason that if an inferior quality was used they could not get the necessary output to make things pay; at the same time, he might add that the great advantage claimed by its introducers for the Siemens-Martin furnace was that a class of coal could be used that would not burn in any other furnace. Some time ago he noticed the phenomena ascribed by the last speaker to sulphur. He analyzed the cinder and found that it consisted entirely of pure magnetic oxide of iron. He also found that the sulphur contained in coal remained in the ash, except when the ash came in contact with the grate bars, which then absorbed it. The amount of sulphur passing off in the flame was almost *nil*. He hardly thought the form of ingot shown by Mr. Fownes was the exact thing; most makers had found octagonal ingots work better.

Mr. MULHERION inquired why Mr. Fownes did not advocate making crank shafts from scrap steel?

Mr. GEORGE ARNISON asked, with reference to a remark which fell from one of the previous speakers, "that it was impossible to obtain sufficient hydraulic pressure to compress forgings," whether Whitworth's fluid compressed steel in hollow crank shafts had not proved satisfactory, and might well be considered superior to forged crank shafts? The shafting of the S.S. "City of Rome" was hollow and of Whitworth's manufacture.

Mr. FOWNES, in replying, said, that he would not twist an iron shaft, but would build it up. He mentioned that the iron manufacturers of Leeds had twisted both their iron and steel axles for years. He had seen them manufacturing their iron axles, which were made out of two big slabs, and he had not heard of any case in which one of their axles had broken in the middle through twisting. Crank shafts could, of course, be made out of a square ingot, but the difficulty was to get an ingot exactly to the size required. He advocated cleaning the scrap with a "rumbler." A "V" mandril would make a square shaft, but it would not make a round one; and what they required was a round shaft. With regard to the question of the laying on of coils for the shaft coupling, he should, if the coupling were a large one, put on three pieces; but probably that was a matter of opinion. The stroke of the hammer had, as the President told them, a very great deal to do with the soundness of the shaft. The stroke was not of so much importance in rounding the ends of the webs, as then, though the stroke was much reduced by the height of the web, a heavy blow was not necessary, as it would tend to open up the longitudinal welds in the crank web. A flaw in an iron shaft usually showed itself before it became dangerous; but his experience had been that in a steel shaft rupture came without any previous warning whatever. The octagonal ingot might be the best for some work, but the shape of the ingot should be governed by the piece they wanted to forge. In conclusion, he said that what little observation he had already made on the subject did not impress him in favour of scrap steel, but rather against it.

A vote of thanks to Mr. Fownes for his paper was proposed by Mr. Macoll and carried unanimously.

FIG. 1.

FIG. 2.

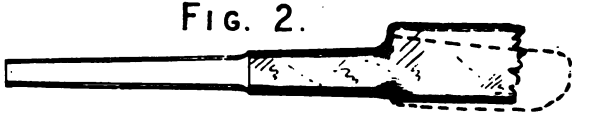
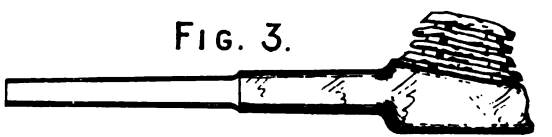


FIG. 3.



Scale ½ Inch = 1 Foot.

FIG. 4.

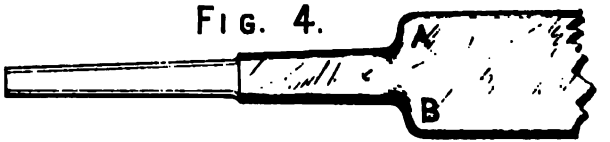


FIG. 5.

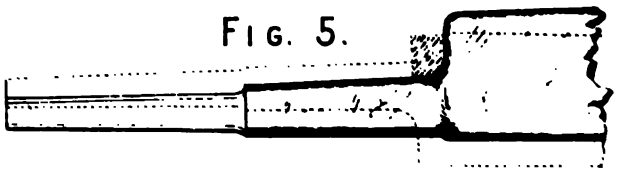


FIG. 6.

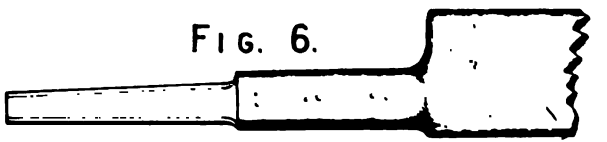


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Fig. 7.

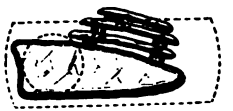


Fig. 8

Fig. 9.

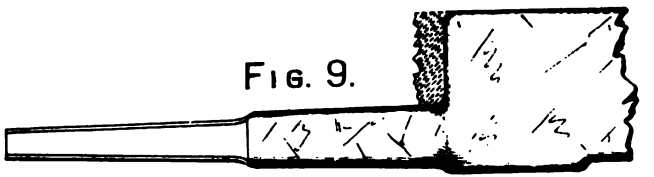
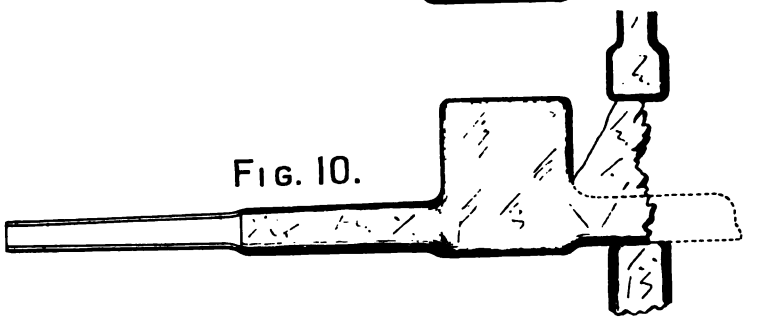


Fig. 10.



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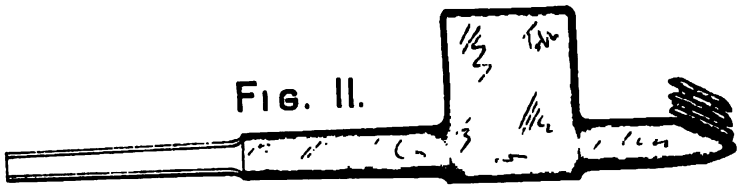

Fig. 11.

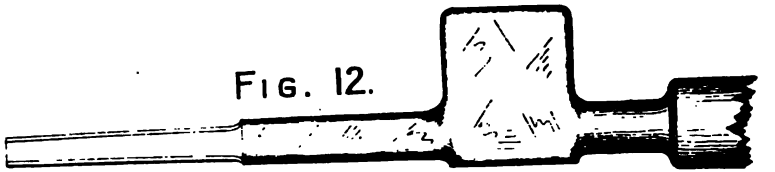

Fig. 12.

Fig. 13.

Fig. 14.

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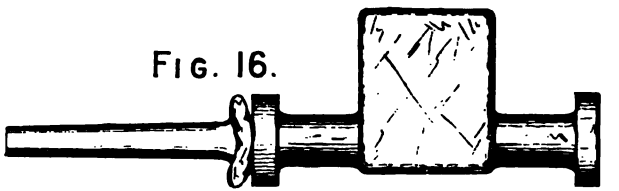
FIG. 15.

FIG. 16.



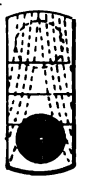
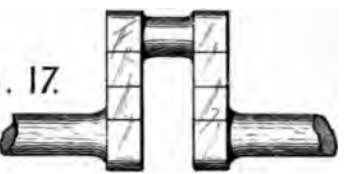


FIG. 17.



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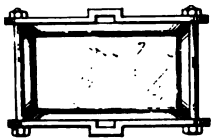
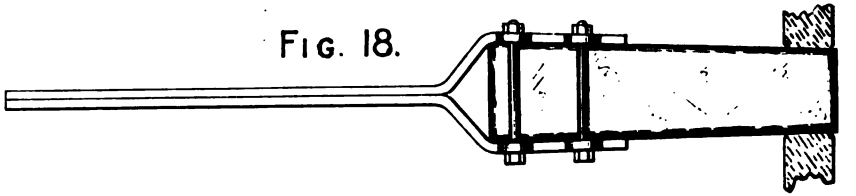


Fig. 18.



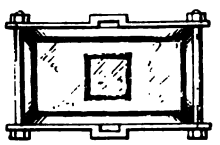


Fig. 19.

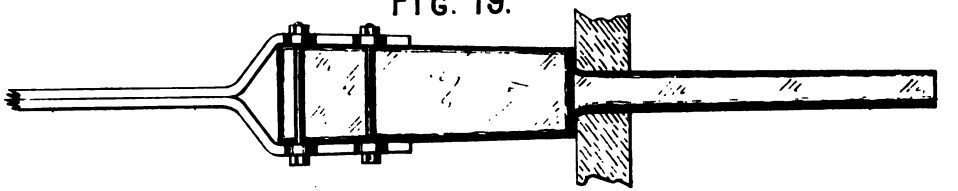
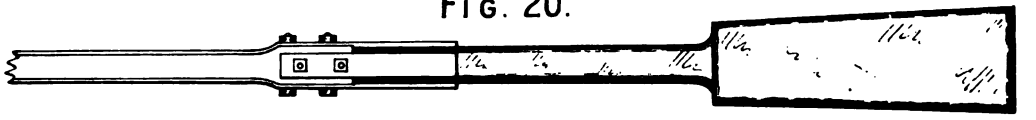


Fig. 20.



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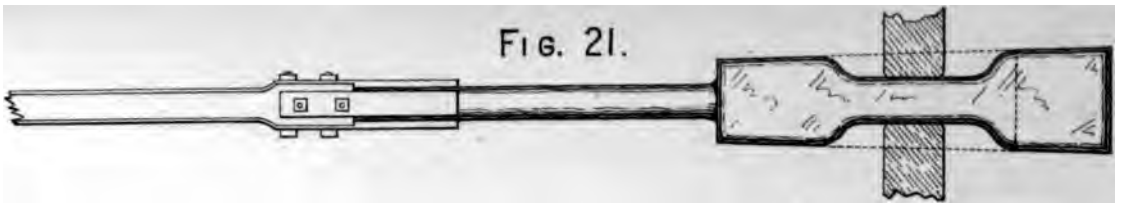


FIG. 21.

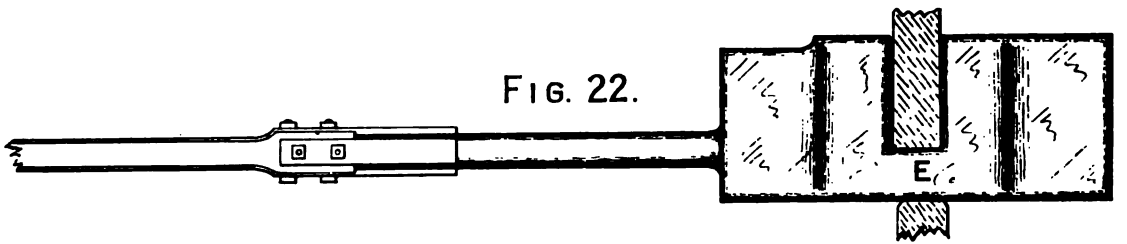


FIG. 22.

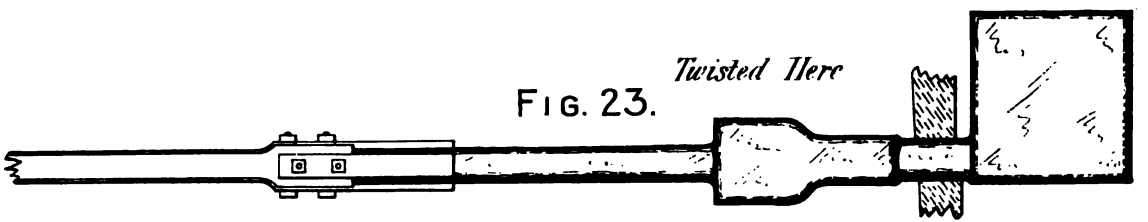


FIG. 23.

Scale ½ Inch = 1 Foot.

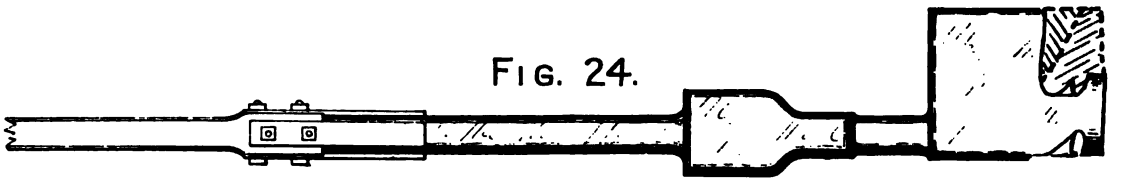


FIG. 24.

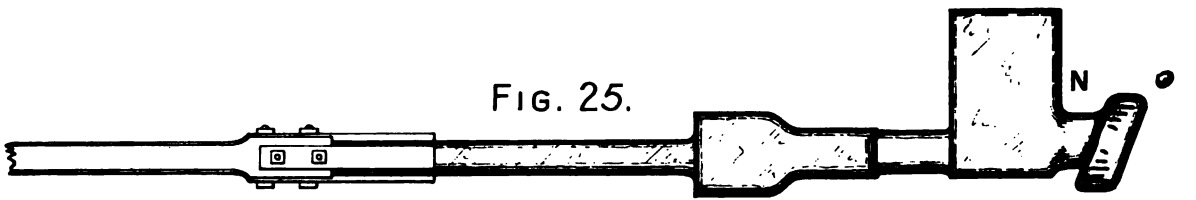


FIG. 25.

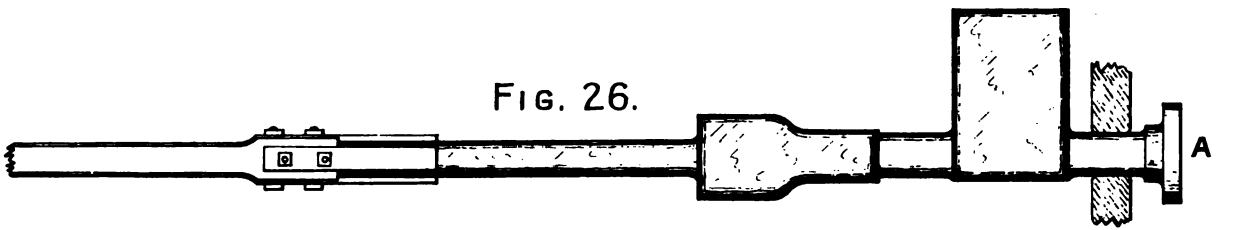


FIG. 26.

Scale ¼ Inch = 1 Foot.

And^r Bein Newcastle

FIG. 27.

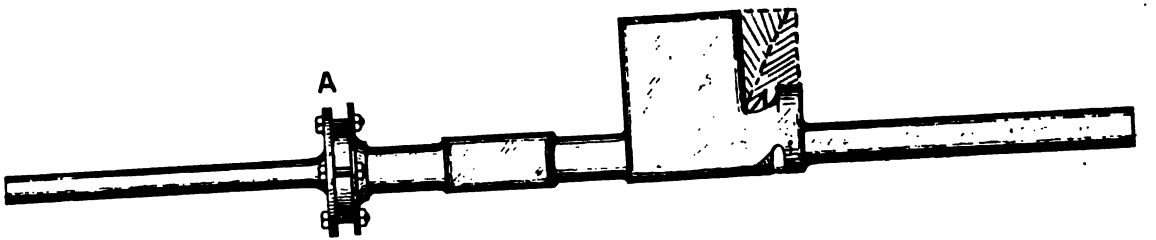
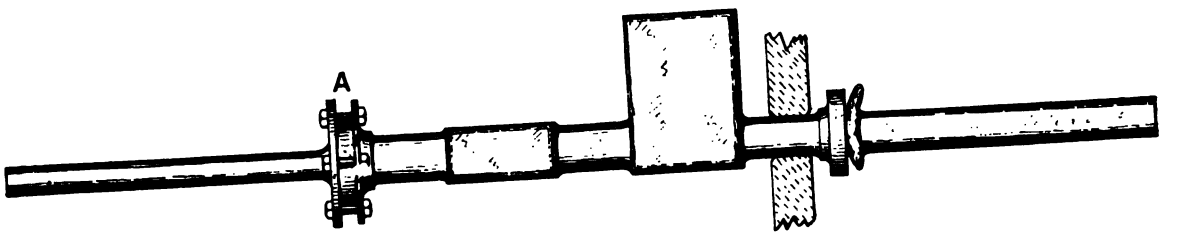


FIG. 28.



Scale ¼ Inch = 1 Foot.

Weight of Forging when Finished about 5¼ tons.

At. Reid, 12th Newcastle.

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.

FIRST SESSION, 1884–85.

GENERAL MEETING IN THE LECTURE HALL OF THE LITERARY AND PHILOSOPHICAL SOCIETY, NEWCASTLE-UPON-TYNE, WEDNESDAY, FEBRUARY 18TH, 1885.

W. BOYD, ESQ., PRESIDENT, IN THE CHAIR.

ON APPROXIMATE CURVES OF STABILITY FOR SHIPS.

BY A. E. LONG.

BEFORE going on to the subject of this paper, the writer wishes to reply first, by anticipation, to some objections that may be made to a paper on stability just now. It may be said that the subject has recently received a very large share of attention, and is now rather overdone from a literary point of view. But the writer doubts if anyone considers that stability calculations are in general use, or anything like it. Also, the use of the integrator may seem to remove all need for "approximate" methods of calculating stability, and has no doubt removed to a great extent the demand for rapid approximations, at least in large drawing offices. There are, however, a considerable number of small establishments where various difficulties are found to prevent its extended use.

As the main object in urging the more extended use of "approximate" methods is to remove objections which are frequently raised to the ordinary method, it will be well to state as clearly as possible

what these objections are. The ordinary mode of calculating is a very long, and a wholly arithmetical one; the arithmetical work being of a peculiarly monotonous character, and therefore very liable to error. The various steps are so intimately connected, that the final result does not afford any check upon the work in most instances.

The calculations, though simple in themselves, are based upon principles not so generally known as they might be; many fairly expert calculators work very much in the dark as regards the principles of the rules they use; this is also an obvious source of error. The resulting curves appear to many persons to give a very small return for so much labour, and this deters such persons from undertaking the work. There are only two methods of checking, and neither of them is satisfactory, they are as follows:—First, the independent calculation for 90 degrees or some other angle, generally stated in text books to be very simple and easy, is very often quite the reverse, especially if there are large erections on deck and a high sheer; moreover, when it does show that there is an error, it gives no information about the position of the error, and looking for it is a tedious process. The second is the metacentric method used to check the initial part of the curve; this, while in any case having only a limited scope, may be, and sometimes is, used for a greater angle than it correctly applies to, and the calculator may be led into carefully searching for an error that does not exist. Many of these difficulties are due rather to the calculators, than to the rules themselves; but we must take things as we find them, and endeavour to supply persons who find these difficulties insurmountable, with alternative methods. An obvious mode of removing the most serious of these objections, is to replace some of the long arithmetical processes by mechanical or graphical ones. Two objects would be gained, the liability to arithmetical errors would be reduced, and the two distinct processes would be made to efficiently check each other. Apart from this, the variety would be a great advantage in practice. Approximate methods of calculating can easily be given, having the advantages mentioned above, and as results can be got by them sufficiently correct for ordinary purposes, it seems advisable that they should come into general use.

The following may be taken as desirable conditions to be fulfilled by an approximate method:—

1. The principle should be quite simple, and its explanation should require the use of as few mathematical expressions as possible. Mathematical reasoning and modes of working have given us our whole stock of knowledge concerning the stability of ships, and to them advances in that knowledge will always be due. But when the knowledge has been gained, and when the liberal use of mathematical terms is found to deter many persons from studying a very interesting and useful subject, it is advisable to avoid the use of such terms as much as possible.
2. The several steps should be as independent of each other as possible, and so give a check upon the results.
3. As the saving of time is often a serious consideration, it is well that the calculator may be able to avail himself of assistance, without thereby endangering the result through the inexperience of the assistant.
4. The resulting diagram should give information for all reasonably useful variations of draught, like the more elaborate and correct methods.

Several of the recently published modes of calculating fulfil most of these conditions; but as the authors of them might perhaps object to the result of their labours being styled "approximate," and the methods have not been sufficiently long before the public to judge of how far they are workable in practice, no further reference shall be made to them; but the writer will pass on to admittedly approximate methods.

The simplest of these was published in a letter to the *Times*, by Mr. Barnaby, and from it copied into *The Steamship*. This method is simply to transfer the immersed sections of the body plan to a sheet of stiff paper. "Cut these out with a pair of scissors, and gum them together in their relative positions, care must be taken to spread the gum thinly and evenly. The weight of these sections represents the displacement of the ship. By suspending this collection of sections from two different points, and taking the intersection of two vertical lines through the points of suspension, the position of the centre of buoyancy is obtained. Draw on the body plan a number of water-lines at various angles of heel, all the lines intersecting at the centre of the upright water-plane. Cut out as before the immersed

sections corresponding to the first inclined water-plane and gum them together. The actual floating line at this angle may be obtained by cutting off parallel slices from the tops of the sections, until the weight is the same as those in the upright position. Find the centre of buoyancy as before by suspending them from two points. The distance between a vertical line drawn through the new position of the centre of buoyancy thus found, and a vertical line through the centre of gravity of the ship is the leverage at which the weight of the ship acts to right herself at this angle of inclination. If this process is repeated for each angle, a complete curve may be obtained."

This, while being simplicity itself, and in careful hands, giving good results—as stated in Mr. Barnaby's letter—is open to many objections. The principle upon which it is based is not a correct one, as the centre of gravity so obtained is merely the common centre of a series of isolated planes, and is not the centre of gravity of the body of which these planes are sections. The difficulties occurring in practice are perhaps less important, but as they are just as likely to combine to vitiate the result as not, their presence is objectionable. These difficulties are: inequality in thickness of the paper used, uneven distribution of the gum, centre-lines not coinciding, and the difficulty of cutting off the correct volume of displacement. To get over these difficulties and objections, and at the same time render the method available for getting more extended information, the writer combined it with Mr. Denny's first integrator method, that invented by Mr. Fellows, namely, paper sections, and a planimeter taking the place of the integrator. By employing this method the usual correction for difference in the volume of the wedges of immersion and emersion is dispensed with, as it is only necessary to obtain a series of values for the righting levers for each angle, and the displacements to which these levers correspond. The displacement thus becoming a variable, instead of a fixed quantity.

A full body plan is required, but this can easily be got by tracing the sections, and reversing to obtain the other side, or any other easy way the operator may select. He then has to determine the number of draughts necessary for the particular vessel, generally four will be found sufficient, and the angular interval. For the latter, Mr. Denny takes 15 degrees, but for an approximate method, 20 degrees generally,

and one or two intermediate angles, will be quite near enough. The draughts should be so chosen that the finished diagram will give "spots" for ordinary stability curves, from the light to the load-line. At some angles and draughts it is necessary to arrange the water-lines so that none of them cut the aftermost section in more than two points, otherwise two centres of gravity will be required for that section.

The sections of the body plan have now to be transferred to sheets of stiff paper, and cut out, as many copies of each section being required as there are angular intervals.

This having been done, and a position of the centre of gravity of the vessel assumed on the centre-line (C G Fig. 1), work can be commenced for the first angle and the *deepest draught*. A line (W L Fig. 1) having been drawn across the body plan at the given angle, planimeter readings have to be taken for each section up to the inclined water-line and entered in a column on paper ruled for the purpose.

Returning now to the paper sections, the inclined water-line (W L Fig. 1) having been drawn across each section in its correct position, the part of the section above this has to be cut off, and the centre of gravity (C B Fig. 1.) of the remaining portion found by suspension. The distance between a vertical line (A B Fig. 1) drawn through this point and a vertical (E D Fig. 1) through the assumed centre of gravity of the vessel may be called the "lever" for this section.

The planimeter readings have now to be multiplied by their respective levers, giving the moment of each section about the assumed centre of gravity of the vessel. The readings and moments have then to be set up as ordinates of curves, the abscissæ representing the distances of the sections apart. It is immaterial what scale is used for either ordinates or abscissæ, but if the planimeter is to be used the scales should be so chosen that the areas of the curves can be got by one traverse of the instrument. The area of the curve of moments divided by the area of the curve of readings gives the righting or upsetting lever for the given draught, angle of inclination, and assumed position of the centre of gravity of the vessel.

The areas of these curves can be got by either Simpson's rule or by the planimeter.

The work for all the angles is similar, as also for all the other draughts except that new sections are not necessary, the required layer

(W L W_1 L_1 Fig. 1) being cut off the original paper sections. We here see the reason for beginning at the deepest draught.

The rest of the work being exactly similiar to Mr. Denny's method, it is only necessary to quote from his paper, with slight variation :—

"The product of the curve of readings and a suitable multiplier is the displacement at the given draught. This process having been performed for each of the draughts at the given angle of inclination, figures are obtained for setting off the calculated displacements as abscissæ (A A_1 A_2 etc., Fig. 2) upon a horizontal base line, and at these points, ordinates, representing lengths of righting levers. A curve through these points is the cross curve of stability for the given angle. Similar work has to be done for each of the angles required, and a series of cross curves obtained, one for each angle."

From these curves, an ordinary curve of stability can be got for any displacement (D Fig. 2), by simply erecting an ordinate (E D Fig. 2) at the position of the given displacement. The intersections of this line with the curves give ordinates for the required curve of stability. It should be noted that the same centre of gravity having been used for all the displacements, a correction has to be made for variations in the height of the centre of gravity, found either by calculation, or by heeling the vessel.

The above-described curves make no allowance for erections on the upper deck, or appendages beyond the extreme sections used ; but any number of appendages can easily be added, by getting their areas and moments in a similar way, and adding them to the respective curves (readings and moments) before finally finding the righting lever.

In the explanation also, the curves of readings and moments have been assumed to have been plotted, but it will be at once seen that the areas can be got without plotting, if the curves have been made from ordinary displacement sections. Much time can be saved by this, but a calculator so saving time loses a valuable check upon his work, for, if the curves were plotted they would show by their fairness, if the preceeding operations were correct. A good deal of interesting information is also given in a graphic form concerning the change in fore and aft distribution of displacement, produced by inclining the vessel, and as to how far the assumption that no such change takes place is correct, or not.

The advantages that can be claimed for this method are as follows:—

1. Only very elementary knowledge is required to clearly understand the process.
2. The various steps are sufficiently distinct to allow of two or more persons working at the same time.
3. The assistant, or assistants, may be comparatively inexperienced.
4. No special apparatus is necessary as almost every office possesses a planimeter.
5. Any body plan which has a sufficient number of sections to give fair lines will do for the calculation. But if the sections are not arranged for Simpson's rule, the curves of readings and moments must be plotted; this, as has been before stated, is in any case desirable.
6. If the curves and sections are kept for reference, a very good idea can quickly be got as to how a modification in form would effect the stability of a subsequent design.

Any estimate of the *time* required to get out a complete diagram by this method is purposely omitted, as it depends to a great extent upon the calculator's powers of rapidly taking planimeter readings, etc., and also upon the amount of assistance that is available. It therefore seems advisable merely to describe the method, and omit particulars which might be misleading.

The writer has in the foregoing applied Mr. Barnaby's paper section method to avoid the use of the integrator in *one* of the new methods of calculating stability. But a little reflection will show that several of the other methods could be simplified in a very similar manner, and also the results could be put into other shapes besides the cross curves herein described.

The method can also be used in conjunction with the ordinary calculation. The writer has done this for racing yachts, in the following manner. It is customary to calculate the curve of stability of these vessels right out to its vanishing point, generally about 180 degrees. These curves are of a peculiar character, and are worth some study, as the conditions are very unusual, and give some insight into the effect produced by manipulating the centre of gravity. Perhaps

on some future occasion this Institution will permit the writer to give some illustrations and comments thereon. At present the curves are calculated by the ordinary method up to about 100 degrees—the maximum point—and completed by the approximate method, which is also used to interpolate points where they seem necessary, such as in the neighbourhood of humps, etc. In this particular case, as only one curve of stability is required, the wedges have to be adjusted before cutting off the upper part of the sections. This adjustment is effected by putting in a trial inclined water-line, and calculating the displacement up to it with the planimeter. If the displacement so found is less or more than the upright displacement, the water-line has to be shifted until the two results are got equal, or as nearly so as may seem necessary for the particular case. It is generally easily and rapidly done, especially for the interpolated points, where the difference in volume of the adjoining wedges is correctly known. The same principle can be applied to any case where the stability at only one draught is required.

The method first treated of has been called "Mr. Barnaby's method," though he clearly stated that it was someone else's property. In the absence of any definite information concerning the inventor, the writer had to do this for brevity's sake.

In conclusion, the writer begs to express a hope that if he has not succeeded in explaining a particular method he has used, he has at least succeeded in interesting some of his hearers in the subject of "Approximate Curves of Stability for Ships."

Mr. MACOLL, in rising to open the discussion, said he was strongly of opinion that the writer of the paper did not require to make any apology for introducing anything in the way of simplifying the subject of stability. It would be well that not only those who were engaged in the construction of ships, but also those who were entrusted with the navigation of the same, should have their attention directed to this subject. Shipbuilders cannot always be obtaining practical experience of ships at sea, and they are in a measure dependent on the reports of the captains and officers who navigate the

vessels, and have gained experience of them in varying conditions of weather and lading. And, speaking generally, seafaring men at the present time have not that knowledge of the principles of stability which would enable the shipbuilder to accept reports of vessels' behaviour at sea without at least considerable caution. And in order to attain a common standpoint, it is greatly to be desired that the subject of stability should be simplified and popularised as it were, as much as possible. In reference to the paper and the cardboard sections, he would like to know how the correction for the angular layer was arrived at. He supposed the area of the level water-line would be first taken, and then the area of the inclined or angled water-line compared therewith and the necessary correction made. Then in the paper it was stated the assumed centre of gravity was to be taken. Was this centre of gravity (which by the way in the diagram seemed very low) assumed from a similar vessel whose centre of gravity was known, or how? It appeared to him it was of the greatest importance that the approximation should be as nearly correct as possible, owing to the effect the position of the centre of gravity had on the length of the lever, or in other words, the measure of the safety of the vessel. The writer of the paper had laid some stress on the point that the length of stability calculations deterred many persons from going into them; this was to a considerable extent true, but still it must be born in mind that a very considerable number of vessels constructed in late years, more especially amongst the East Coast collier and coasting class, were anything but deficient in stability; in fact, in his experience a very large number were somewhat troubled with an excess of stability, especially when in water ballast; and in several cases lately, comparatively new vessels had been fitted with bilge keels or rolling fins in order to prevent or lessen the excessive rolling. For several years past steamers have gradually been increased in beam, in proportion to other dimensions, and, no doubt, increased beam is in some cases a very good thing, both from a stability and also from a small load draught point of view. Still, the greatest advocate for increased beam never intended the beam to be carried so close to the extreme ends, as is now sometimes done to such an extent that what in the newspapers are called splendid specimens of naval architecture, approach closely the proportions and capacity of a rectangular box, and in this case we have the short, quick

rolling, which is so objectionable. He might say that he had not only been interested but instructed by the paper he had just heard read.

Mr. TREWENT agreed with Mr. Long that the large amount of arithmetical work necessary to arrive at the usual curves of stability had deterred a very large number of private firms from going much into the subject of stability. The curves that had been calculated had chiefly been done by the larger firms, such as Messrs. Denny's, Palmer's, and Mitchell's, and many smaller firms had not gone into the question at all. Mr. Long had said the method under discussion was approximate, and he (the speaker) thought it might be new to a great many of them; but, although he had seen it before, he had never seen any comparison between the results from this method and the actual calculation. He should be very glad to know how near or how approximate it really was, and whether it came anywhere near the actual results got at by full and detailed calculation. The firm with which he was connected had, in their small way, tried to calculate a few curves of stability; they had inclined several classes of steamers, both light, in ballast, and loaded, and he might correct the previous speaker when he said that all the vessels built in this neighbourhood had ample stability. He (Mr. Trewent) knew that some of the larger class of ships built on this river had anything but a surplus of stability when loaded with a homogeneous cargo, such as coal. He thought the height of the metacentre was generally low; and would like to know what the best authorities on this question of stability considered the least metacentric height for ships should be, loaded, as these vessels were, to a deep draught, with a freeboard even less than Lloyd's tables required. The safe amount of stability was at present a matter of individual opinion, no recognised law had been laid down. They wanted more information before they could work on anything like the proper lines in designing their ships. Mr. Denny's cross curves of stability were very valuable. As time went on he had no doubt they would still further increase the beam, and thus add to the stability; but it must not be forgotten that in vessels of this class a foot or so more freeboard will greatly improve the curve of stability, and in many cases make an unsafe ship into a safe one. He hoped some of the younger members would introduce some method by which they would arrive at the required results without the long calculations they had at present.

Mr. MACLEAN said, in reference to the different approximate methods enumerated in Mr. Long's paper, that he (Mr. Maclean) considered the description of Mr. Barnaby's method rather ambiguous. He had got excellent results from it, agreeing exactly with those from the integrator and the ordinary tedious method; but he knew some of his friends had not been so successful, and perhaps Mr. Barnaby's method should be more generally known. He first took a large sheet of smooth drawing paper, and stretched it on a board as much as possible; he then took a tracing of the equidistant sections of the ship, and pricked each one through separately for the upright and different angles of heel, carefully placing the inclined water and centre lines on each section, and allowing a margin on the inclined sections at the top of the water-lines to enable him to adjust the weights of the different inclinations with the upright condition. After cutting out the sections exactly to the points and carefully gumming them together with thin gum, so that they each had the same centre and base lines, he squeezed them gently in a press; and got all the sections ready for adjusting for weight. He would add that in gumming it was necessary to place the sections in order, and gum them in groups of four or five at a time. He then took the upright condition sections, which were all cut to their proper water-line, and placed them in one scale of a balance; and taking the inclination set of sections, planed down the margin parallel to the water-line till the weight of these sections agreed with the weight of those in the upright position, and so on for all the different inclinations. He then suspended the inclined sections, and found their centre of gravity, which gave the correct position of the centre of buoyancy of the ship when inclined to that angle; and knowing the height of the centre of gravity from the inclining experiment, he could get the lengths of the righting or upsetting levers for the different angles of inclination, and thus form the curve of stability. He might state that he had only used this method as a check on the accuracy of the integrator, that machine giving the righting levers in much less time, and its manipulation was so simple that a comparatively inexperienced person could get out stability curves more quickly and accurately by it than could be done by any of the approximate methods. In referring to Mr. Long's method, he considered that in getting out the volumes, etc., the process could be shortened considerably, if, whilst

using the planimeter, instead of taking readings at the end of each section traversed, they took simply three readings, viz., at the end of the two ends and the odd and even sections, care being taken, if the planimeter was not of the latest type, to note the number of times the ten's recorder passed zero. He thought the question put by the last speaker (Mr. Trewent) rather wide in its scope, and considered that it could not be answered generally, for the metacentric height in the upright condition did not always give a correct idea of the stability of the ship; for a ship might have what was apparently a safe metacentric height in the upright position and yet lose it altogether on being inclined to 20 or 30 degrees, or even less. It was necessary to have stability curves for the load and light draught of the vessel, to ascertain if the least metacentric height had been attained at which the ship would be workable in a certain trade or carrying certain cargoes; and it could also be defined what cargoes the ship could and could not carry.

Mr. HECK said that with regard to paper sections his experience was not satisfactory. He never could get two sheets of paper to weigh exactly alike. He had tried all kinds of paper, but had not found any two weigh exactly the same, and the difference in weight of the paper would make a difference in the result. He considered the question of stability was one that would have to be gone fully into. The integrator was no doubt a very useful instrument and should be in every drawing-office, as anyone accustomed to its use could by its help easily work out a set of cross curves such as Mr. Denny described in his paper last year. He would like to see the examples of Messrs. Swan and Hunter, Messrs. Mitchell and Co., and others, followed, viz., having their ships inclined before they left the river.

Mr. MAVOR, in speaking of the time occupied in making an inclination, said, that Mr. Denny informed them that with a well-trained and thoroughly organised staff he could do the work in 40 minutes, but, he Mr. Mavor, considered it could be done in rather less time, for, with favourable conditions as to weather, four inclinations could be taken in half-an-hour. He was sorry Mr. Long had taken up a view so common amongst calculators of stability. Many papers that had been produced lately had been designed to make a simple matter appear simpler, and to save calculation as much as possible. He thought they should rather endeavour to develope the calculating powers of the younger

members of the profession. He did not advocate the use of the integrator too largely, as it tended to create a class of people who could not calculate a column of figures correctly without some such mechanical aid. With regard to the accuracy of Mr. Barnaby's method, he had not himself carried out the work, but he understood that with care in cutting and gumming the sections a very close approximation could be arrived at.

Mr. Alexander Taylor thought the paper was misnamed and did not deal with a ship's stability. He had hoped to hear of a ready method of locating the centre of gravity of various types of steamers, together with the centres of gravity of homogeneous cargoes which would just fill the ships; and of a simple method of locating the centres of buoyancy of these various types of ships at various draughts and angles of heel; but, instead, he finds the most important element, namely, the centre of gravity, is simply assumed to be somewhere. To him as an engineer, the paper appeared simply another method of finding the centre of buoyancy. In this case the centre of buoyancy is found by a combination of two methods, one of which the writer condemns and then uses. The writer condemns the use of paper sections because, as he says, they are incorrect in principle, and liable to error on account of irregular thickness and irregular distribution of gum and defective adjustment, and he might have added unequal stretching of the paper when damped by gum. And yet the writer instantly after this condemnation adopts these paper sections with most of their defects and combines them with portions of another method, and calls this compound his approximate curves of stability for ships. He might say that so far as the statical stability of the ship was concerned at the particular angle of heel shown upon the diagram, it mattered little whether the C B was shifted up or down any distance, the righting moment remaining the same; but at that inclination it made all the difference if the centre of gravity was moved up or down in the centre of the ship. The great want is not another method of locating the C B but some reliable simple plan of showing where the centre of gravity of ship and cargo is for each voyage; and by way of illustration he stated that if the C G was shifted from its assumed position the cross curves would be quite changed and useless. He remembered the first calculation he made

to find the centre of buoyancy of a ship in inclined positions; after calculating the wedges of immersion and emersion, he was very much troubled to know what to do with the correcting layers, he thought Rankine said subtract them while he reasoned that they should be added, he ultimately added them, and re-made the calculations on the corrected water-lines, and found the differences of the wedges had practically vanished. At that time the idea occured to him to try paper sections as a practical test, and the result was so satisfactory that he has often since used paper sections. However, he cannot understand how any man with common sense can expect satisfactory results from gummed paper sections; they are objectionable both on account of the weight of gum, and the liability of the user to unevenly distribute it over the paper. He finds the better plan is to stitch the sections together with fine sewing thread (of which a yard is ample and its weight is practically *nil*) and then iron them out perfectly flat and straight. He was convinced that of all the approximate methods, the paper sections are the best and safest, and he would place more reliance upon their result than upon the results of the most elaborate method he had seen worked out. With regard to the vital point, namely, the position of the centre of gravity of ship and cargo, he was quite satisfied that many steamers were missing through the centre of gravity being too high, and he might say that all the steamers recorded missing in the last four years wreck registers were loaded steamers, and the missing steamers for 1881–82 only averaged four years old and were proportionally of much greater depth of hold than the average steamers. We may build steamers with the best and safest deck arrangement and give them large freeboard, and yet through their proportions or loading they may be unsafe. We must have more information on the C G of ships and cargo.

Mr. Maclean thought that the last speaker was mistaken with regard to the necessity of the exact position of the centre of gravity being known in preliminary calculations; he said that the calculator has to make these curves from the *design* of the ship, and has, therefore, to take an assumed position for C G, and then find the righting levers from this assumed point. After the ship was built, and its true centre of gravity found from an inclining experiment, it was a very simple calculation to make the new curves for the correct

centre of gravity; for suppose we took the top of the keel to be the assumed position of the C G, then the righting lever thus found from it is greater than the true righting lever, by the height of the true centre of gravity above the assumed, multiplied by the sine of the angle of heel. The height of the centre of gravity of the ship for any cargo carried, supposing we know its position for the light condition, can be easily found if we know the weight of cargo and its position in the ship, and new curves of stability can then be got out to suit this centre of gravity of ship and cargo.

Mr. Taylor asked if in the case of a ship being ordered into dock to load pig iron and coke, and the master ordered the pig iron to be put in the 'tween decks, and the coke below, or *vice versa*, how they were to tell where the centre of gravity of that ship and cargo was? he also wished to know if it was at all likely that the owners would detain the ship until the necessary calculations had been made.

Mr. C. W. Hutchinson said that the discussion, within the last few minutes, had been running in a direction that he was anxious to hear it take, namely, enforcing the necessity of accuracy in the fundamental point of a set of calculations. It happened that the paper throughout had reasoned upon an assumed centre of gravity as the basis of calculation; and someone had described different arrangements of cargo and stowage so as to vary or change the centre of gravity; but it must be borne in mind that calculations of stability are very often made and their results required during the course of design of a vessel. At that time, cargo experiments cannot be tried, and if the calculations are to possess any value, the C G, which is the basis of these calculations, must be accurate, or as nearly so as is possible. Under a fixed condition of vessel the C G is a fixed point, whatever be the angle of heel or roll; but, with every variation of the angle of roll, the C B, or centre of buoyancy, changes. To show the importance of accuracy as to the C G, it will be seen, on reference to the canted diagram, that every inch that the C G is lifted, it approaches nearer to the vertical line passing through the C B, and every inch that the C G is lowered, it departs further from the vertical line passing through the C B, thus, any movement of the C G (which must always be on what we may term the line of the ship's mast, or the angle of roll) lengthens or shortens the lever of righting movements.

It is, therefore, of prime importance that by analogy or by calculation this point be arrived at as nearly as possible. He should like to know Mr. Long's opinion as to the extent of angle for which the usual forms of calculation could be followed for metacentric figures. He thought Mr. Taylor was a little too severe with respect to gumming the paper sections. He (Mr. Hutchinson) knew Mr. Barnaby to be a man of the most shrewd common sense, and the system which he had published he plainly said was not his own, yet his shrewd common sense had led him to consider that it was a fairly reliable system. The gumming process required to be carefully done, and if, after placing the gummed sheets together, they were put under a letter-press, and the superfluous gum squeezed out, he thought a good deal of the difficulty could be overcome. He could not agree with Mr. Maclean, who advocated taking a number of areas with the planimeter for one reading. The planimeter is limited, and it is much better to read frequently; otherwise, while the reader might be perfectly correct in his units and decimals, he might easily be wrong in his tens. He was glad to see brought forward some means of simplifying the laborious processes of stability calculations other than the use of the integrator; for, useful as that instrument undoubtedly is, stabilities will often have to be worked out without its aid.

Mr. James C. Spence wished to point out that, instead of using an arbitrary point as C G, and making the calculations from that point, the work is simplified by finding the actual point where the line through the centre of buoyancy cuts the centre line of the ship, and cross curves may be laid down of the actual position of this point. With regard to Mr. Taylor's remarks that all that was required was the position of the centre of gravity of the ship. He (Mr. Spence) would object that the stability depended on the relative position of the centres of gravity and buoyancy, and the finding of the one without the other was useless; he considered that calculations, such as the one given in Mr. Long's paper, were not useless, but were as important as the finding of the centre of gravity, which point could best be determined without calculation by some such process as that adopted in Mr. Taylor's stability indicator.

Mr. Jacob Wallau thought that the shipbuilders might supply captains with a statement showing the curves of stability for cargoes

of various kinds. It would serve as a guide to the captain, and would show him what he could safely do and what not. He did not think the shipbuilder could have any difficulty in supplying such information.

Mr. MAVOR said that a table for one combination of cargo would be quite useless for another combination of cargo.

Mr. WALLAU added, that no doubt some knowledge on the part of the captain would be necessary, but a table might be arranged to give the average height of the centre of gravity for various combinations of cargo. He considered the suggestion was quite practicable.

Mr. HECK said that Mr. Denny now gave a pamphlet to all who ordered a ship from him, in which he described and gave particulars of the variation in the stability of the ship under various conditions of loading.

Mr. A. E. LONG in replying to Mr. Macoll, said that the correct position of the water-line on the section was taken in a wholly arbitrary manner to suit the judgment of the operator, but it must be taken in the same position on the body plan and paper sections. The so-called centre of gravity was merely taken as a point of departure, in fact. The lower it was taken the better it was for convenience, as negative moment points in the curves were thus avoided.

In reply to Mr. Trewent, he said that some results would be given in an appendix which would show the comparative accuracies of several methods of calculation.

With regard to Mr. Maclean's remarks, he said the paper was written chiefly to explain his method; and some parts of Mr. Barnaby's letter had to be omitted to reduce the paper to a reasonable length. But he thought sufficient had been given for the purpose in view. It was to avoid the errors mentioned that he introduced the method of calculation described in his paper.

In reply to Mr. Heck's remarks he said that in the proposed method the weight of the different paper sections was immaterial, as the centres were got separately, and not as a whole, as in Mr. Barnaby's method, after being gummed together. Inclining ships was, to his knowledge, becoming almost a general thing, in some at least, of the yards on the Tyne. He considered that half-an-hour was ample time for the process, at least for two inclinations.

With regard to Mr. Mavor's remarks, his (Mr. Long's) experience

of heeling experiments showed that if such experiments were conducted in a tide-way they were quite unreliable. As regards the using of an approximate method instead of the correct one, he only put it forward to be used by persons who otherwise would make no stability calculations whatever.

In reply to Mr. Taylor, he said that a paragraph in the paper would show him that the centre of gravity, for any *particular* curve of stability, had to be taken from a heeling experiment. His (Mr. Long's) objection to Mr. Barnaby's method was, not to the paper sections, but to the method of using them. Mr. Barnaby used them as isolated planes, but his (Mr. Long's) method took them as the sections of a solid. The centre of gravity referred to by Mr. Maclean on Fig. 1 was an *assumed* centre of gravity for the *vessel*, and had no reference to the centre of buoyancy.

In reply to Mr. Hutchinson's question, his opinion was that the extent to which the metacentric method could be used was that in many merchant ships 10 degrees was rather too far to use it.

The PRESIDENT said that while he must admit himself to be unable to offer any remarks on the subject that would be worth their while listening to, he thought some of the statements made by Mr. Taylor deserved their earnest attention. There was no doubt whatever that at present greater interest was being given to the subject of stability than had ever been given to it before; and he hoped that when shipbuilders had agreed on some of the cardinal points, on which a good many of them seemed to differ, that some system of ready application would be devised by which the stability of laden ships could be more perfectly predicted. That the average ages of the vessels unaccounted for in 1882 was only four years was a very pregnant fact, and he hoped the Institution would take a share in calling greater attention to the subject, and induce the young members of their body to devise some means for the ready application of those rules. He considered the paper a valuable one, and emanating from a junior member afforded, he hoped, a good augury of what would be forthcoming in the future. He had great pleasure in moving a vote of thanks to Mr. Long for the paper he had given them.

The vote was heartily accorded.

APPENDIX.

RECEIVED 2ND MARCH, 1885.

The following notes may be useful to any one wishing to put the method explained in the paper into practice. The water-lines at different angles and draughts, if all drawn upon the tracing of the body plan, make it rather confusing, and spoil it for any other purpose. This can be avoided by proceeding in the following manner:—Having decided upon the number of water-lines, and their distance apart, rule off, on a sheet of white paper, the required number of parallel lines at the given distance apart, and somewhat longer than the greatest breadth of the body plan. Across these lines draw another set of lines—with different coloured ink—representing the relative position of the centre line of the vessel when heeled to the angles previously determined upon. It is most convenient to make these lines all radiate from the centre of the upper water-line. It is now only necessary to mark the position of the upper water-line on the centre line of the tracing of the body plan, and so place the tracing over the paper that this point comes upon the intersection of the radiating lines with the upper water-line; keeping this point in position, turn the tracing round it as a centre, until the centre line of the body plan coincides with the radiating line for the required angle. The planimeter readings can now be taken for all the draughts at this angle. Proceeding in a similar way for all the other angles, the whole of the readings required can be got without confusion.

It is generally best to take the "assumed centre of gravity" at some even number of feet above the top of the keel, and to so place it that all the "centres" of the sections will be upon the same side of the vertical drawn through it.

The number of vertical sections to be used depends largely upon the form of the vessel, but half intervals at the ends are generally unnecessary.

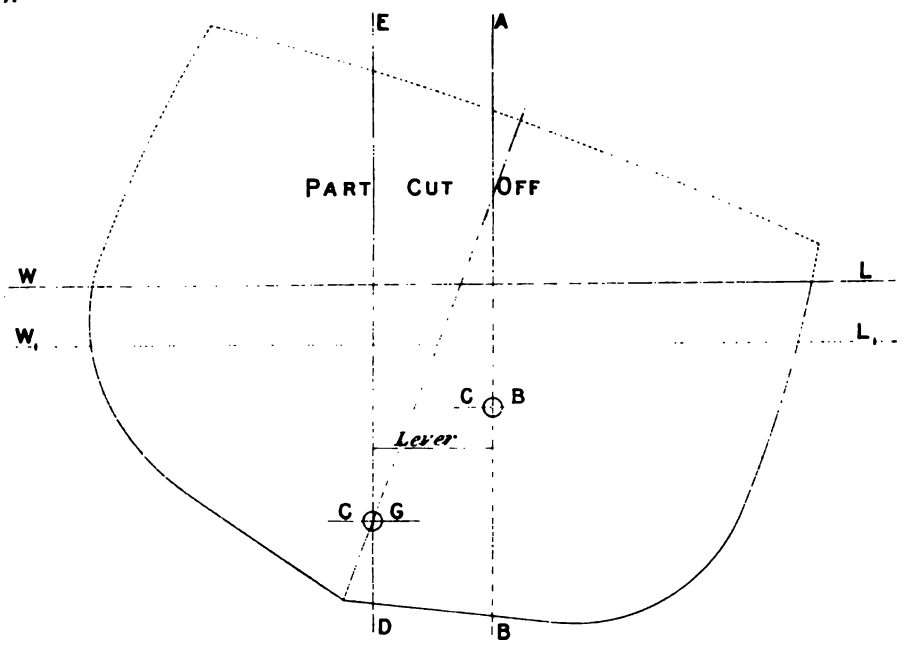
The following examples show how the method compares with both the ordinary calculation and with the integrator. The examples have

been chosen from very different types of vessel, the first being a small vessel with fine lines and a low centre of gravity, the second a large ship of considerable fulness. In some cases the results obtained by this method are more correct than those got by the ordinary calculation, as—like the integrator—its accuracy is not effected by discontinuity of the surface.

	1st Example.		2nd Example.	
	Old Method.	Approximation.	Integrator.	Approximation.
Lever at 20 degrees ...	1·06′	1·09′	0·91′	0·89′
„ 40 „ ...	2·12′	2·15′	1·03′	1·03′
„ 60 „ ...	2·99′	2·93′	0·29′	0·30′

The diagrams given with this paper merely show the mode of working, and do not represent the curves for any particular vessel.

Fig. 1.



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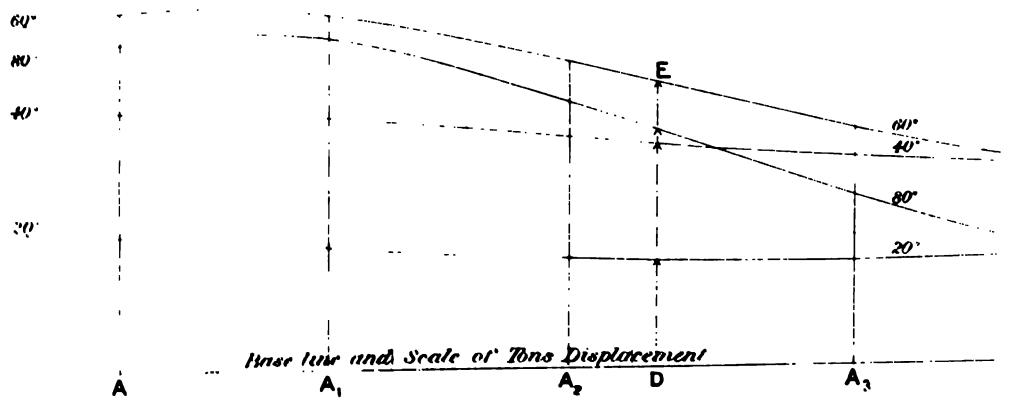
Art Repl. Lith. Newcastle

FIG. 2.

CROSS CURVES.



NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.

FIRST SESSION, 1884–85.

GENERAL MEETING IN THE ASSEMBLY HALL, SUNDERLAND, WEDNESDAY, MARCH 18TH, 1885.

W. BOYD, ESQ., PRESIDENT, IN THE CHAIR.

ON MARINE BOILER CONSTRUCTION AND PRESERVATION.

BY JOHN A. ROWE.

THE President of this Association, in his eloquent inaugural address, spoke as follows on the subject of marine boiler pressures :—"I venture to record my opinion that the triple expansion engine, working on three separate cranks, is destined to become the marine engine of the future." "Whether we shall find ourselves stop short with an expansion of, say twelve times, as in the present triple expansion engine, with a working pressure of 150 lbs.; or whether, as may very possibly be the case, we shall advance to fifteen or seventeen ratios of expansion, by the employment of four cylinders of increasing diameter and a working pressure of 200 to 250 lbs., remains to be seen; but before this can be done, some material modification will be necessary in the boilers at present in use."

Gentlemen, one of the aims of the writer is to introduce certain "modifications" in the construction of boiler shells, which will allow of higher pressures being used with the same immunity from accident that we have had in the past. Another aim is to perfect the system of boiler preservation, so that when we have good boilers committed to our care we may at once adopt reliable means to prevent them corroding and otherwise deteriorating

In the writer's opinion, the difficulty before engineers is not in dealing with flat surfaces, which, by being indented, may be made stiff enough by staying to resist the highest pressures; nor in furnaces, which if corrugated, will afford the necessary strength; but rather in the shell, which, by reason of its great diameter, will require plates of excessive thickness to reduce the stress per square inch of section to a safe working limit.

You need scarcely be reminded that steel has almost entirely superseded iron in the construction of marine boilers. The quality of good mild steel is such that, with a tensile strength of from 28 to 30 tons per square inch of section, its elongation is about 20 per cent. This, then, appears to be an admirable material with which steam boilers and steam vessels may be constructed. Compared to average iron, it is superior in strength and toughness, and so homogeneous as to admit of plates being worked into boilers without regard to the question of grain. Owing to this quality of homogeneity, it is probable that the circumferential seams of steel boilers are stronger than the circumferential seams of iron boilers, in the proportion of 28 to 19.

In spite, however, of its virtues, steel, like human nature, is not quite perfect. Some plates bear within them elements of self-destruction; and even the best quality requires to be carefully treated during the process of boiler construction, otherwise it may become seriously injured and permanently weakened.

The following observations are gleanings from a very instructive book, entitled, "Steel Experiments," issued by the Engineer Surveyor in Chief of the Board of Trade and his assistants:—Thin plates possess a greater tensile value than thick ones. Plates $\frac{1}{4}$ inch thick have stood a tensile stress of 36 tons, while plates 1 inch thick broke at $29\frac{1}{2}$ tons per square inch. Thick plates, with punched holes and unannealed, show a serious loss in strength and ductility. The section of metal left between rivet holes (holes drilled) offers, when the pitch is not great, a higher tensile resistance per square inch than the unperforated plate. This singular phenomenon is probably due to the form of the specimen; the closeness of the edges of the holes to each other, by localizing rupture, prevents the metal between the holes drawing gradually out to a minimum area.

Pitching of Rivets.

Another important fact brought to light by Mr. Traill and his staff is the converse of the above, viz. :—When the pitch of the rivets becomes excessive, the tensile resistance of the plate between the rivet holes is less than that of the solid. This was clearly proved with plates $\frac{3}{4}$ inch thick and below. With plates 1 inch thick and upward it is probable that large pitches may be used without reducing the strength per square inch of the metal between the holes below the strength of the solid plate. But experiments are sorely needed to demonstrate what are the limiting pitches for plates of different thicknesses ; and it would, in the writer's opinion, be well to speak of joints not only as single, double, or treble rivetted, but to give the pitch of rivets in terms of plate thickness. How many plate thicknesses may we with safety pitch our rivets in plates from $\frac{3}{8}$ inch thick up to $1\frac{1}{4}$ inch? It used to be thought that the difficulty of obtaining a *tight* joint was the only objection to the use of joints having a percentage of section of from 80 to 90. Mr. MacColl, in 1875, thought that "the only barrier to the adoption of wide pitches (90 per cent. of the plate) lies in the real or supposed difficulty in making them tight at high pressures." It now would appear that another consideration, of almost equal importance, bars the way to the use of joints having a percentage of section much above 80. The problem then to solve to-day is to construct a rivetted joint with a percentage of section so great as to reduce an abnormal plate thickness to a limit where good workmanship may be ensured ; to space the rivets of such a joint in a way to ensure tightness ; and to prevent the tensile resistance of the metal between the holes becoming less than the tensile resistance of the solid plate. The writer, with some degree of diffidence, intends to present methods of rivetting which, he hopes, will, to a large extent, fulfil the above requirements.

Percentage Curve.

The full size diagram of a percentage curve, which hangs upon the wall, enables us to perceive how simple has been the task of advancing from 50 to 75 per cent. of section of joint. Observe how slowly the ordinates increase in height from 50 to 60 per cent., and from 60 to 70. From 70 to 80 the sweep upward is more pronounced, whilst the

curve from 80 to 90 is so abrupt as to point to the hopelessness of the attempt to obtain, by ordinary methods, a joint possessed of 90 per cent. of section. The curve is constructed in the following manner:—The base line is divided into percentages. The vertical lines marked 1·67, 2, 3·35, etc., are the ratios which the pitches of the rivets bear to the diameter of rivets; the diameter being unity. Thus, in a 50 per cent. joint, the ratio or ordinate is 2. In a 70 per cent. joint the ordinate is 3·35; in an 80 per cent. joint 5; in a 90 per cent. joint 10, and so on, up to infinity, for the solid plate.

Those who have had experience in boiler designing are well aware how difficult it is to obtain sufficient rivet section when a high percentage of section is required with thick plates. A glance at the curve before you will explain the cause of this difficulty. Compare, for instance, the ordinate over 80 with that over 90. The latter is twice the height of the former; and this means that the plate section of a 90 per cent. joint is at least twice the plate section of an 80 per cent. joint; and, as the rivet section varies as the plate section, it follows that we require at least twice the rivet section for a 90 per cent. joint that we require for an 80 per cent. one. The difficulty of reaching from 80 to 90 per cent. may be illustrated in another way. Assuming that in the 80 per cent. joint we are dealing with 1 inch plates, it is as difficult to obtain 80 per cent. of rivet section with a 2 inch thick plate as it is to obtain 90 per cent. rivet section with a 1 inch thick plate. It would be a decided gain if, with lap-joints, the shearing strength of the rivets of longitudinal seams were equal to the tensile strength of the shell plates. Perhaps with rivets in double shear it would not be an advantage to use rivets of such a quality, seeing that their bearing surface is not now too great; and where insufficient bearing surface exists, it is probable the joint would yield by distortion of holes and rivets long before the nominal bursting pressure was reached.

The writer is hopeful that the curve of percentages may win its way into favour, for the following reasons:—It enables one to instantly compare joints of different percentages; it shows in a graphic manner the difficulties we are face to face with when designing high percentage joints; and by the aid of suitable formulæ it enables us to design joints of given percentages that shall be equal in plate and rivet section.

The current practice in drawing offices is to design a joint in the following manner :—

When P = pitch of rivets in inches,
d = diameter of rivets in inches,
t = thickness of plate in inches,
a = area of rivets in square inches,
n = number of rows of rivets,

Then when d, t, and n are given, the joints are designed by the following manner :—

(1) $P = \left(\frac{\frac{23}{28} \times a \times n}{t}\right) + d$ when rivets are in single shear.

(2) $P = \left(\frac{\frac{7}{4} \times \frac{23}{28} \times a \times n}{t}\right) + d$ when rivets are in double shear.

These formulæ enable us to design joints equal in sections of plate and rivet (the rivets in double shear being allowed $1\frac{3}{4}$ times the value of rivets in single shear ; and the rivet section being $\frac{23}{28}$ times the plate section), but they tell us nothing about the percentages of sections of the joints. These must be discovered by computation ; and it not unfrequently happens that when a joint is designed and computed the sections of joint are found too low or too high, and the joint has to be re-designed. Now the curve before you, with the appropriate formulæ, enables us to approach this task with scientific certainty ; and when the joint is designed there is no need to compute its worth, seeing that the mode of construction determines it from the beginning.

Let R = ratio of pitch to diameter of rivet,
t = thickness of shell plate in inches,
n = number of rows of rivets,
d = diameter of rivets in inches.

It is required to find the diameter of rivet and pitch for any given percentage of joint.

Rule for lap joints $\frac{(R - 1) \times t}{\cdot 645 \times n} = d$

Rule for double butt strapped joints $\frac{(R - 1) \times t}{1 \cdot 129 \times n} = d$

} And $d \times R = P$

We will now apply at least one of the rules. It is required to construct a common double butt strapped joint, having a percentage of section of 85. The plate is $\frac{3}{4}$ inch thick; the number of rows of rivets to be four.

$$\frac{(R - 1) \times t}{1{\cdot}129 \times n} = d$$

$$\frac{(6{\cdot}7 - 1) \times \frac{3}{4}}{1{\cdot}129 \times 4} = 1 \text{ inch bare (say 1 inch).}$$

And $1'' \times R = 1 \times 6{\cdot}7 = 6\frac{3}{4}''$ pitch.

Thus we have designed a joint which we know, without further calculation, possesses sections of plate and rivet of 85 per cent.; but if any one should be in doubt as to the correctness of the rule, perhaps he will kindly run the figures out and ascertain whether the joint is really what it is stated to be. Fig. 1. represents this joint; and carrying the eye along to Fig. 2, you may perceive how MacColl's joint is, or should be, constructed, and what its worth is.

MacColl's Joints.

I have heard remarkable statements made concerning the value of MacColl's joint—statements which would not be surprising if coming from the lips of a tyro, but which are simply astounding when made by men who are supposed to be possessed of plenary inspiration on the subject of boiler construction.

Figures 1 and 2 represent the common system of rivetting, and MacColl's. They possess the same plate section, the same rivet section, and their caulking pitch inside and outside is the same, viz., $6\frac{3}{4}$ inches. It is impossible by any system of rivetting yet put forward to construct a joint in the mode known as MacColl's, which shall possess a greater percentage of joint than can be obtained by the old system. MacColl's treble rivetted joint is simply four rows of rivets disposed in three lines, and is very well suited to high percentage joints. It is unsuited to joints much below 80 per cent., owing to the small plate section of the centre line. There is this superiority in MacColl's system, the shell plate is shorter than in the common system of rivetting to the extent of four diameters of rivets. The modes of rivetting now about to be described are methods which the writer has

endeavoured to perfect with the view of combining strength and tightness in one and the same joint. They are referred to as the "Tyneside system of rivetting."

Tyneside Rivetting.

Fig. 3 is a sketch of an "open butt joint." Instead of bringing the plates close together as in ordinary butt joints, they are left open a space of about four plate-thicknessess. A butt strap, fitted either inside or outside, is rivetted to the shell plates, and care must be taken to make the strap thick enough to prevent rupture through the line of close-spaced rivets. The centre rows of rivets, A, are pitched only $4\frac{1}{2}$ inches apart, and they are $1\frac{5}{16}$ inch diameter. The rivets of the outer lines are pitched $6\frac{3}{4}$ inches apart, and are $1\frac{1}{8}$ inch diameter. The shell-plate is $\frac{3}{4}$ inch thick, the strap a little over $\frac{7}{8}$ inch, and the joint is 83·3 per cent.

Comparing this with Figs. 1 and 2, we find it superior to them in offering facility to secure tightness, inside and outside. On one side where the $1\frac{5}{16}$ inch rivets are pitched $4\frac{1}{2}$ inches apart, this superiority is very pronounced. On the other side, where the $1\frac{1}{8}$ inch rivets are pitched $6\frac{3}{4}$ inches apart, the superiority, though small, still exists, and is the difference between the closing effect of an $1\frac{1}{8}$ inch rivet and an 1 inch one.

In Figs. 1 and 2, the pitch inside and outside is $6\frac{3}{4}$ inches, with an 1 inch rivet. These joints are 85 per cent. against the Tyneside's 83·3. It is, however, scarcely fair to the latter to be compared with joints whose rivets are in double shear. The system of rivetting represented in Fig. 3 is offered as an improved form of lap joint. It gives tightness by the close spacing of rivets, and is circular in shape. A little care on the part of the boiler-maker would, one would think, enable him to turn out an excellent job with this rivetting. A common lap joint possessing 83·3 per cent. of section would, with $\frac{3}{4}$ inch plates, require to have four rows of $1\frac{7}{16}$ inch rivets pitched $8\frac{5}{8}$ inches apart. Compare this with No. 3.

The writer's next step forward is illustrated by Fig. 5. Two plain (unscalloped) butt straps connect the shell plates. One strap is wider than the other; one taking two rows of rivets, the other three rows. The rivets are pitched as in Fig. 3; and the diameter of the outer row

of rivets is less than the diameter of the inner rows. The writer attaches great importance to this feature, as high percentage of plate section is thus rendered possible without the employment of excessive pitches.

In this 85 per cent. joint the outer caulking pitch is only $5\frac{1}{16}$ inches, against the $6\frac{3}{4}$ inches of Figs. 1 and 2; the inner caulking pitch is only $3\frac{7}{8}$ inches against their $6\frac{3}{4}$ inches. The plate is $\frac{3}{4}$ inch, the rivets of lines A and B are 1 inch diameter, the rivets of line C are $\frac{7}{8}$ inch diameter.

Fig. 4 represents the latest development of the Tyneside rivetting. The inner strap is so rivetted to the shell and the narrow butt strips as to offer an easy means of producing tight workmanship by inside caulking; whilst the disposition of the outer strips is such that, even though the outer rows of rivets were spaced a foot apart, the caulking distance, being the *vertical* distance between the rivets, would always be reliable. This joint should suit, in an admirable manner, boilers with *welded* shell plates, if shell plates ever should be safely welded.

In regard to this system, it may be said that the butts would require caulking. Well, if the butts should leak in ordinary butt joints, the leak finds its way to the edges or ends of the straps, and at such points it is stopped by the hammer, and set. But what takes place? The steam or water, being enclosed, is more or less destructive, by eating away the inner surfaces of the straps on which the strength of the boiler depends; and some engineers cannot be induced to construct double butt strapped boilers; and others who have used them have abandoned them, because they fear the corrosion which at times takes place on the inner surfaces of the covering straps. Now in Fig. 4, if a leak should show itself at the butt, it may be stopped at the butt. It cannot easily injure the strength of the thick outer strips. In this joint the inner strap and outer strips would be about the thickness of the shell plates. Although Fig. 4 is designed with $\frac{3}{4}$ inch plates, this peculiar system of rivetting will probably be found more suitable to thicker plates, and to welded joints. We will now pass on to the subject of caulking.

Caulking.

In boilers built of thick plates, the evils which result from severe caulking have not, so far as the writer is aware, manifested themselves

to a serious extent. In boilers with thin plates the case is different. The writer has sat inside a boiler whilst caulking proceeded outside, and has watched the effect produced by a "quarter hammer" vigorously applied to the punch and sets. As the blows descended, minute quantities of scale flew off the surface of the plate, and a faint whitish coloured line betokened the direction of the tool. Now if in longitudinal seams the practice should become common in thin plated boilers to pitch the rivets governing the landing edges from 10 to 11 plate thicknesses apart, the writer is of opinion that the greatest care will need to be exercised to prevent permanent injury being done to the plate underlying the lap which is being set up. There is scant wisdom in gaining 10 per cent. of section of joint by careful work in the drawing office, if the practice of the boiler yard should reduce the value of the plate 25 per cent.; and wide pitches are, in the writer's opinion, a strong inducement to the men to use the quarter hammer with a vigour not usually indulged in when close spaced rivets are in question.

It has been said that "Corrosion follows the caulking tool." This may or may not be true, but assuredly there is some truth in the observation that the caulking tool may determine the factor of safety of the boiler.

Sometime ago a small marine boiler, built of $\frac{3}{8}$ inch shell plates, lapped joints, for a working pressure of 30 lbs., burst at the water test a little before twice the working pressure was reached. It rent through the solid plate, close to the landing edge of outer plate, following in an exact direction the course of the caulking tool. A friend of the writer's, a most able engineer, reported on the case as follows:—"The cause of the rupture of the plate at so low a pressure would appear to have been due to defects in the plate. It is, however, not satisfactory to accept the theory off-hand, since, if it be so, it is very singular that the defects should be so local as not to extend to a line of rivet holes, less than one inch distant, where about 40 per cent. of the material was punched away."

You see, he argued, that if the plate was of inferior quality throughout it ought to have rent through the line of rivet holes, not through the solid plate.

Commenting on the above report, one of the greatest living authorities on boiler construction wrote as follows:—"This boiler had a

nominal factor of safety of not less than 7·2, but its real value was under 2; and, so far as we know at present, this sweeping reduction of the factor was chiefly due to defects in the material, either original, or caused by subsequent treatment. Had its resistance been slightly greater, the hydraulic test would have passed off satisfactorily; and the boiler would, no doubt, have been placed on board ship, in the belief that it was in all respects what it appeared to be, and that it possessed a factor of safety sufficient to cover all contingencies."

Now, gentlemen, if the plate which ruptured was of the usual quality, and had not been injured by "subsequent treatment," it would have possessed, through the solid where it rent, an *actual* factor of safety of 7·2, inasmuch as that its value was not depreciated by *mode* of construction. Now what reduced the factor from 7·2 to a little below 2? The writer is not prepared to speak positively on this point, but practical boiler makers of large experience will aver that few men can be safely trusted to caulk the seams of boilers. Some do not grind the sets to the proper angle, others do not hold them at the proper angle, and others again employ more strength than is necessary where thin plates are concerned.

Perhaps enough has been said on this subject; but it is desirable at this juncture to call attention to the evils which may arise from unskilful or severe caulking, seeing that high pressures are coming to the front conjointly with, relatively, thin shell plates. One of our most eminent members has declared that a saving of one ton in weight of machinery means an annual gain of £10 to the shipowner. This, of course, refers to fairly prosperous times. Another talented member, who is credited with having originated a type of triple expansion engine, will, no doubt, still press onward from 150 lb. pressures to 300 lbs.; thus thin shell plates and high pressures seem fated to be ushered into use together; and it behoves each one of us to do his best to perfect the art of rivetting, so as to give security to those afloat, and confidence to those on shore. We will now proceed to the subject of boiler preservation.

Boiler Protection.

Probably some of you are aware that an article on boiler construction and preservation, from the writer's pen, appeared in the April and May numbers of the "Nautical Magazine" of 1884. The subject, so

far as preservation is concerned, was treated then more fully than it is possible to do in the limits of this paper. More than a year, however, has passed since the article was written, and during that time much valuable experience has been gained on this all-important subject. It is a subject which, in the writer's opinion, has been permitted too long to rest in the shadow which want of knowledge of electro-chemical action has thrown around us; and as Mr. W. H. White pleaded for progressive speed trials, so the writer would plead for superintending engineers to carefully carry out, in concert, pre-arranged systems of preserving marine boilers from corrosion, so that after say twelve month's fair trial of the rival methods now in use we may be able, by comparing results, to definitely decide which method is the best and cheapest.

The internal portions of marine boilers, cylinders, slide, and cylinder faces, have frequently been known to have been injured by the corrosive action of the acids freed by the decomposition of vegetable and animal oils. Now, however, that mineral oils are generally used for internal lubrication, pitting and wholesale corrosion from this cause is seldom complained of. The chief cause of corrosion seems to be galvanic action.

Galvanic Action.

When two plates, one electro-positive to the other, are brought into metallic contact, and surrounded by an exciting or corrosive liquid, like acidulated water or salt water, galvanic action immediately proceeds, and the plate which is the more susceptible to corrosion wastes away, and to a very great extent preserves the other plates to which it is united. This is seen in a galvanic battery where the zinc plate is frequently renewed, whilst the copper remains comparatively unaffected. In marine boilers it is probable that the purer qualities of iron and steel are electro-positive to plates containing larger admixtures of phosphorus and carbon; and when we have in one and the same boiler plates rivetted together, possessing different susceptibilities to corrosion, it must follow that the electro-positive plate will corrode. Now for many years the Admiralty have protected the boilers of men-of-war by hanging inside, in the water spaces, slabs of zinc, and as zinc is electro-positive to the most electro-positive iron or steel plates, it

follows, when good metallic contact is effected, that the inner surfaces of the boiler are perfectly protected from corrosion. Mr. Bakewell, of the Admiralty, has stated recently that the boilers of the "Iris," after seven years' use, show no signs of wear. The "Champion's" boilers, after six years' use, show no signs of wear. The "Carysfort's" boilers, after six years' use, have worn $\frac{1}{64}$ inch on the shell plates and $\frac{1}{32}$ inch on the tube plates. Surely this speaks volumes for the efficacy of zinc. But. besides the question of prevention of corrosion, is another important one, viz., how to remove lime deposits from the boiler, especially from the heating surfaces, where their heavy accumulation may result in explosion or collapse; and from whence they are removed only with great difficulty and loss of time.

In regard to the effect produced upon lime deposits in boilers by the corrosion of zinc, the Admiralty Committee, which sat some years ago to investigate the subject of boiler corrosion, etc., reported as follows:—"The hard and adherent scale which is generally found when zinc is fitted, appears to indicate that the presence of zinc has the effect of hardening the scale and fixing it to the iron." Since that time it is probable such experience has been gained as to justify one in writing as follows:—When very weak currents of electricity are produced by the corrosion of zinc in a boiler, they tend to cause the scale which forms on the inner surfaces to adhere, just as weak currents of electricity promote electro-plating; but when stronger currents are established they prevent deposition, and loosen the hard adherent scale which for years has been inaccessible to scaling tools. In support of this view, Professor Guthrie, in his excellent book on electricity and magnetism, writes as follows concerning the electrolysis of a weak solution of acetate of lead:—

ELECTROLYSIS.

"It is necessary that the battery power be not too great, else the hydrogen is evolved at the negative electrode along with the lead, owing to the simultaneous decomposition of the water in such quantity that it does not meet with sufficient lead in its immediate neighbourhood to reduce, and some of the gas escapes as bubbles, which interfere with the regularity of the metallic deposit."

Thus we have the evidence of a talented electrician that a rapid decomposition of water will, by the separation of the hydrogen from the

oxygen, prevent deposit taking place on the surface of the negative electrode; and as the iron surfaces of the boiler are negative to the zinc, and the hydrogen bubbles escape vertically from the iron plates, it follows that zinc, efficiently employed, is not only a preservative against corrosion, but an excellent agent to remove the carbonate and sulphate of lime which frequently gives so much trouble.

Protection by Zinc.

Several engineers who, twelve months ago, had no faith whatever in the efficacy of zinc, have recently informed the writer that after twelve months trial they are so convinced of its great protective power that they would not abandon its use for anything. At the same time, the writer is aware that the claim set up that zinc will loosen lime deposits is one that has not always been borne out by facts. On this point the following is worth relating. About eighteen months ago the engineer of an establishment on the Tyne had his attention called to the subject now under consideration. Under his charge are two land boilers fed by town water, and the deposit from this water adhered so tenaciously to the shells and furnaces as to necessitate the employment of two men for the greater part of a day every fortnight. They experienced great difficulty in removing the scale by chipping-hammers, and the marks on the furnace crowns and shell sides bear witness now to the severity of former practice. Willing to try so simple a plan the engineer fitted zinc balls to the boilers, the zinc being attached by wires soldered to the zinc and to the iron plates. In order to corrode the zinc a small quantity of salt was periodically introduced; and now, at the end of eighteen months' regular working, the engineer informs the writer that the scaling tools have never once been used since the introduction of zinc; and the writer's own experience enables him to state that what deposit is found in the boilers when they are opened monthly for examination, is so soft as to be removable by one's fingers.

It must, however, be confessed that zinc has not always exerted this beneficial action, either afloat or ashore; and the writer now begs to draw attention to one defect in the method of its use. We have already had evidence to show that a sufficiently powerful current of electricity will prevent deposit taking place of an adherent nature. We also know that to obtain a good flow of electricity there must be

good connection between the zinc and the iron or steel plates; but so far as the writer knows, but little attention has been paid to the condition of the zinc itself, and this is a feature which is worth calling attention to.

When zinc corrodes in salt water, the oxygen of the water combining with the zinc forms an oxide, which at last becomes a perfect crust outside of the surface which should always be accessible to the attack of the salt water. This crust, if not frequently removed, may hermetically seal the zinc within, and thus, no matter how perfect the connection may be, the electric current ceases to flow, protection ceases, and scale is deposited just as if no zinc were fitted. So, if the writer's opinion were asked as to the reason why, in one set of boilers, zinc well fitted loosened the scale and in another set failed to do so, he would reply that it was, in his opinion, due to differences between the condition of the crusts which formed on the surfaces of the zinc. Is there, then, any means by which this crust can be kept porous or soft, so as to ensure constant corrosion of the enclosed metal?

Protection by Zinc and Soda.

A few months ago, a superintending engineer who had no faith in zinc, but great faith in soda, assured the writer that the boilers under his care were in splendid condition, both as to absence of pitting, corrosion, etc., and also as to their freedom from scale. At his request the writer surveyed the boiler of one of his vessels, and found that his description of its excellence was not overdrawn. The zinc fitted was in slabs suspended from the longitudinal stays, and the quantity of soda used was 2 lb. per day per ton of coal consumed. The boilers are said to run for voyages extending from 40 to 45 days, soda being introduced daily (carbonate of soda), and the scum cock only being used occasionally to remove the froth from the surface of the water. The blow-off cock is seldom touched. Asked as to density of water at the end of so long a voyage, it was stated to be sometimes over $\frac{4}{32}$; and seeing that the writer was interested in the subject, a bottle of boiler water was sent to his house for the purpose of chemical analysis. Instead, however, of endeavouring to analyse the solid ingredients it contained, the writer

constructed two small galvanic batteries for the purpose of ascertaining what difference, if any, was made upon the positive and negative plates by the boiler water, $\frac{3}{32}$ strong, composed of salt water and soda, and by water rendered $\frac{4}{32}$ strong by the addition of common salt.

After they had been in operation about a month they were examined, and the following notes were recorded by the writer:—"The copper and zinc plates of salt water battery encrusted above water by a slightly-adhesive white-looking scale, which the application of red litmus paper proves to be an alkali—soda in fact. The under-water portions of the plates somewhat discoloured, the zinc looking as if an oxide were forming on its surfaces.

"The copper and zinc plates of boiler-water battery have slight, white, feathery-looking deposit upon them, above the water-line. A breath removes this deposit. Below water the plates are as clean as the day they were put in. Red litmus paper proves the deposit to be alkaline."

These experiments, though conducted on a small scale, were thought by the writer to be of considerable value. However, the theory of protection by soda and zinc was tested on a large scale in the Tyneside establishment already referred to. For two months, two boilers side by side were worked, one with soda solution and zinc, the other with salt solution and zinc. The oxide around the zinc in the first-named boiler was found to be easily removable by hand; it crumbled away under the fingers. At the same time, the deposit was found to be in the condition of soft powder. The oxide around the zinc in the second boiler was harder, and was removed with greater difficulty; but the deposit was, to all appearances, as soft in the one boiler as in the other. The boiler in which soda was used was much whiter than the other. This, no doubt, was caused by the formation of carbonate of lime, the carbon of the soda uniting with the lime to form chalk, whilst the sulphur of the lime combined with the soda to form sulphate of soda, a soluble salt. This conversion of sulphate of lime into carbonate of lime by the use of washing soda is a most desirable process in marine boilers, as the latter salt is much more easily removed than the former. Thus, so far as two months' test is concerned, the theory deduced from observing the action of the two small galvanic batteries, appears to be sustained; but a few months

will settle all doubts on the subject, as the two boilers are daily at work side by side, one having a small quantity of soda weekly introduced, the other a small quantity of salt.

Protection by Dynamo Electricity.

There yet remains a method which experiment may prove the best and cheapest for large steamers. It is this:—By simple and suitable machinery connected with the main engines (machinery the writer is designing) a feeble current of electricity may be sent through the whole of the boilers during the time the engines are at work. Insulated wires should be introduced at opposite ends of the boilers, below the water-line; and as, in order to complete the circuit, the current of electricity would have to flow through the water, a sufficient quantity of hydrogen would be set free to cover the inner surfaces of the boilers with a protective film, and prevent scale deposits or corrosion taking place. One wire should be fastened to the boiler shell, the other wire to a mass of zinc; and, in the writer's opinion, it would be preferable to fit the zinc outside the boiler in a small vessel constructed on purpose to receive it. This vessel should be attached to the boiler by means of a cock or valve, which should usually be open, but which could be closed at will, so as to admit of an examination and cleansing of the zinc at any moment. This arrangement seems to be desirable, having regard to the fact that some superintending engineers who have approached this question of zinc protection, etc., in a candid frame of mind, and have tested the scheme in several vessels, have nevertheless, after several long trips, abandoned the use of zinc balls, because, they say, they have facilitated the adherence of scale rather than loosened it. The writer is unwilling to dispute their experience, but he hopes that this paper will be the means of explaining how zinc may be used in a way that will give every satisfaction. If zinc be well connected to the iron surfaces, and its own surface be kept pervious to the attack of the corroding liquid, it will, in the writer's opinion, be effective both in removing scale and preserving the boiler from corrosion. Zinc in any form will answer the purpose; but the purest *quality* should be used, otherwise a local galvanic action in the zinc itself will be set up, which will form around it an oxide negative to itself, and thus rob the boiler of the protection it stands in need of.

Mr. PATTERSON said that Mr. Rowe had succeeded in bringing before them some very interesting points in boiler construction. Mr. Rowe seemed to have made a very good joint, and he had also shown them very clearly the nature of the joint called MacColl's, as it was usually constructed, and as Mr. Rowe had depicted it in Fig. 2. It was simply a common joint with double butt straps and four rows of rivets. If they compared that joint with the joint in diagram Fig. 5, it showed a $6\frac{3}{4}$ pitch both inside and outside, as against $5\frac{13}{16}$ pitch on the outside and $3\frac{7}{8}$ on the inside, in the case of the Tyneside joint, which was considerably against MacColl's joint, and a very important point in favour of Mr. Rowe's. However, Mr. Rowe has hardly done MacColl's joint sufficient justice, for it is evident that with a fixed diameter of rivet, the pitch for any percentage of plate will be the same in MacColl's joint as the pitch of the outer row in the Tyneside joint. He had had occasion to design several of these joints, and was very well satisfied with them. With regard to Figs. 3 and 4, they might be very good joints, but he could not say much about them from experience. Perhaps some other of the gentlemen present might be able to explain their qualities. Mr. Rowe gave them a formula which he thought would be very useful in designing a joint. Until that morning he thought the formulæ were quite new, but he discovered that morning that the same formulæ were contained in Mr. Foley's book in a different shape. Mr. Rowe had mentioned in his paper how desirable it would be to obtain rivets equal in shearing strength to the tensile strength of the shell plates. He saw no reason why the steel manufacturers could not supply them with such, without sacrificing the elasticity of the material. Perhaps Mr. Rowe would give them his opinion upon that subject. He wished to draw attention to one point in connection with the preservation of boilers that Mr. Rowe had not touched upon. He referred to the difference of temperatnre between the top and bottom of a boiler, more especially when steam was being raised. This source of decay was said to be overcome by the introduction of the hydrokineter. When he was in Sweden, a few weeks ago, he saw a very much simpler contrivance, which answered the same purpose. It was simply a propeller placed in the water at the bottom of the boiler; the shaft, passing through a stuffing box in the front end of the boiler, was worked by the fireman, and thus

kept the water circulating while steam was being raised. The following particulars were from a pamphlet published by the patentee; the degrees given being degrees centigrade. A boiler fitted with the patent propeller began to raise steam at 9·15 in the morning, and the following are the results:—

With Patent Propeller.			Without Patent Propeller.		
Time.	Temperature at Top.	Temperature at Bottom.	Time.	Temperature at Top.	Temperature at Bottom.
	Degrees.	Degrees.		Degrees.	Degrees.
9·15	8	8	8·30	6	5
9·30	12	8	8·45	9	5
9·45	20	22	9·0	17	6
10·0	38	38			
10·15	50	51			
10·30	67	68			
10·45	80	82			
11·0	92	96			
11·45	98	98			

The temperature remained at 6 degrees at the bottom, while the top increased from 17 to 48, 74, 90, 92, 97, 97, and 97 at 10·45. He thought that clearly showed that the use of the patent propeller served a very good end. He would also like Mr. Rowe to explain to him how he would apply his formula in designing a joint of the class shown in Fig. 5.

Mr. McKay said they were all very much indebted to Mr. Rowe for his very able and instructive paper. He had seen the joint designed by Mr. Rowe, and he was sure it would work its way into notice and actual practice. At the present time they had quite a battle of joints, and it was possible that a new joint would rise up and eclipse Mr. Rowe's. Mr. Rowe had touched on the subject of decay in marine boilers, and from what he could gather he (Mr. Rowe) fixed on galvanic action as the chief cause of decay. He quite agreed with him; he had always considered galvanic action to be the great cause of decay in the internal parts of marine boilers. As to the use of zinc in boilers, there were engineers who had had experience of it and had found no benefit therefrom. Any person who had constructed a galvanic battery, however simple, would know that if a very small particle of grease, or anything of that nature, formed at the point of contact of the two metals, it would instantly cause the current to cease. And in

applying zinc to marine boilers, the failure to find benefit from the use of the zinc was, he considered, due to the inefficient way in which it was attached to the boiler. The question might be asked—Why does the zinc decay, even if metallic contact with the boiler be broken? He had thought this over. This decay, he thought, was due, in a great measure, to local action, and to the presence of brass or copper tubes in the surface condenser; the zinc of commerce containing iron and other metals negative to itself. Indeed, the reason why rolled zinc is preferable is, that the adulterated article cannot be rolled out with success. They knew that in connecting a galvanic pair—zinc and copper for instance—they had a very strong current set up for a short time, and then it nearly ceased altogether, on account of the surface of the copper becoming clogged. Of course they knew that when zinc and copper were put into a tumbler with a little acidulated water—common salt and water or dilute sulphuric acid—there was a galvanic current instantly set up. The zinc, being the positive metal, decayed. There was no galvanic action without decay. The zinc decayed and the water was decomposed; the zinc took oxygen and formed oxide of zinc, and the hydrogen was liberated from the surface of the copper, which, as he said, soon became clogged, and the circuit nearly ceased, or at least became very feeble. If, instead of iron and copper, they substituted a plate of silver, or what they called platinised silver, which liberated the hydrogen with greater rapidity from the small atoms or points of the platinum, a battery of greater power and certainty would be obtained. Was it not possible that the atoms of brass carried from the condenser tubes, and mingling with the water, acted as the platinised silver did, even though the zinc was not in metallic contact with the boiler? Mr. Rowe spoke of a Tyneside firm which had been successful in the introduction of zinc into boilers, and mentioned that the wires were soldered to the iron. In that case they had perfect metallic contact; and so long as that remained, he believed the zinc would be of use; and for this reason, that they had the zinc as a positive pole and the boiler shell as a negative pole. The zinc took its own place as in the battery, and the boiler shell became the negative pole, as the copper, or iron, or platinised silver. The hydrogen would be liberated on the surface of the boiler plate, and small bubbles of hydrogen would be continually

rising, thus preventing the scale from adhering to it. An engineer in the service of the P. and O. Company had told him that when in India he had a set of internal feed-pipes fitted to one of his boilers; these, from lack of other material, were made of zinc. On the way home the old boiler behaved itself admirably, on account of these pipes having been fitted; but on the boiler being surveyed on reaching England, only the stumps of the pipes were found remaining. Mr. Rowe spoke of two plates of different natures being rivetted together, setting up a galvanic current. Mr. Rowe did not require to get two plates for that. If he took a steel plate, and punched a piece from one corner, a piece from the opposite corner, and a piece from the middle, on testing them with the galvanometer he would probably find one corner negative to the other corner, and both corners negative to the middle. There was another source of electricity in connection with boilers, discovered by Sir W. Armstrong forty years ago. They knew that when a new locomotive went for the first run, there was generally a good deal of trouble on account of priming; and to cure this (speaking of twenty years ago), the custom was to run it into a shed and blow the water off, and then clean out the boiler with soda and water, and it was generally all right ever afterwards. To save that bother, they used, when the steam test was over, to open the scum and gauge-cocks, and let the grease run off the surface of the water before the boiler was put on the frame. At the same time they used to try an experiment in electricity. When, under certain conditions, steam issues from an orifice, there was, as they all knew, a shower of electric sparks. In blowing off the grease he used to observe a curious phenomenon. Before the scum and gauge-cocks were opened, the steam was positive, and the boiler negative; but as soon as the oil was blown off the conditions were entirely changed; instead of the steam being positive and the boiler negative, the boiler was positive and the steam negative. He would only, in conclusion, mention a circumstance which happened on board H.M.S. "Vanguard." One of the engineers on board the vessel told him of this circumstance, which they had not been able to find a reason for. It was the engineer's duty to see the stop-valves screwed down; and on one occasion, just after screwing one of them down, the casing burst like a shell. The valve case seemed strong enough, and no one could account for the accident. There was no zinc in these old-fashioned boilers; but

the steam, owing to excessive heat through superheating, would become decomposed. The hydrogen, being a light gas, would come into the upper part of the valve case, probably charged with atmospheric air from the water, and, if ignited, would cause the explosion. Might it not have been that a spark from the electricity generated by the steam, had ignited the mixed gases in the casing and caused the explosion? Perhaps Mr. Rowe would give them his opinion on the subject?

Mr. W. A. CRAWFORD said he would like to ask Mr. Rowe, whether it had been clearly proved that thin plates possessed a greater tensile value than thick ones, and that the section of metal left between rivet holes (holes drilled) offers, when the pitch *is not* great, a higher tensile resistance, and when the pitch *is* great, a less tensile resistance per unit of area than the unperforated plate, or whether the results given might not be accounted for by the method of conducting the experiments. If the statement that thin plates are stronger than thick ones were read "plates of small section are stronger than plates of large section," then the remarkable statement about the sections between the rivet holes would be accounted for. If the Board of Trade had made experiments on the subject he had seen no publication of them. Some time ago (1879–80), when experimenting for Sir Wm. Thompson, a number of interesting facts were deduced from a series of experiments with wires of different metals placed under tensile stress. For instance, these wires, made of soft iron, stretched, with about 40 lbs., 15 per cent. When the weight had been allowed to hang for about a week it was increased, and the wire eventually broke at 50 lbs. He might say the tensile value of the iron was about 40 lbs. They tried several of these wires, and one of them was allowed to remain under stress for nearly six months, and increased 50 per cent. in tensile strength, so that it was pretty clearly proved that soft iron, slightly strained in the direction of breaking, became stronger. It had been said that with boilers of higher pressures (150 lbs.), it was dangerous and prejudicial to test them by cold water to a pressure of 200 or 300 lbs.; but the result of the above experiments would show it to be really beneficial to a boiler to test it to a very high pressure.

Mr. JAMES J. PEARSON said that before coming there he had an opportunity of reading Mr. Rowe's paper, and had made one or two

notes of his own personal practice in relation to zinc, covering in all about twenty new boilers. That zinc plates did protect such metals as were electro-negative to them, when immersed in the same exciting medium, few would doubt. The question at issue seemed to him to resolve itself into the amount of protection, and length of time for which such protection was afforded; in other words, could they depend on this protection being continuous for a given time, or must they rely on the old practice of a protective scale? His own experience was in favour of zinc alone, when placed in proper amounts in a new boiler. It also went to show that no two boilers, however equal their working conditions, consumed equal amounts of zinc in equal times. The usual practice was to suspend zinc plates of such dimensions that the term "slab" would be an apter name. Given that these were hung in the usual manner in the spaces between the nests of tubes, and that the boiler had been under steam for say 30 days. The engineer inspecting would likely find such plates as were in place very much warped, and with a surface protected by a thick friable corruscation, which he would recognise in part as oxide of zinc, coated with certain insoluble precipitates found in sea water. On breaking the plate, and examining the section, two-thirds of its thickness would be found oxidated with a completeness that varied with the depth. The centre would be very little worse than when the entire plate was first immersed, but, as examined from centre to side, the action showed to have penetrated freely for the first $\frac{3}{16}$ inch, the next $\frac{1}{16}$ inch with more difficulty, and so on—the difficulty increasing with the distance penetrated. After the exposed surface of a plate was once oxidised to the depth of say $\frac{1}{8}$ inch, this oxidated layer became protective to that immediately below it. Now the question was, what thickness of oxidated coating was required to render the ordinary commercial zinc electro-negative to iron? Suppose the plate be $1\frac{1}{2}$ inches thick, and that the action penetrated $\frac{1}{2}$ inch on each side, leaving $\frac{1}{2}$ inch of unoxidised zinc in the centre, the $\frac{1}{2}$ inch on each side could only be penetrated by a series of increased efforts proportioned to the increased difficulty—at last there was a balance—and then the increasing resistance of the thickening layer of various oxides reached a point that was virtually electro-negative to iron, and oxidation was accordingly set up elsewhere. Now this happened before all the zinc was oxidised for the centre layer

still existed, but so thickly encrusted as to be utterly useless. Acting on this idea, he some time ago had plates cast ½ inch thick, 36 inches long, and of a breadth that would just permit their passage through the manhole. These were hung in the tube spaces by hangers secured to the stays, and at the end of a 45 days' passage, about 6 square inches of plate remained. The boiler was in capital condition, and without a sign of corrosion. The quantity of zinc which he had found in practice to give best results was from 40 to 72 square inches for every ton of water the boiler contained, at mean working level, this to last a 30 days' passage. There was one matter which seemed to him to be worthy of their special attention, and that was the unequal behaviour and state of boilers supposed when built to be duplicates, and submitted when working to conditions which were practically identical. When two metals were immersed in a slightly acidulous liquid, a simple voltaic couple was formed, which only required electrical contact to become closed. Immediately on this taking place, one metal became a positive electrode, and oxidated at a rate proportional to the conditions. The fact that varying qualities of iron were used in the construction of a boiler, no doubt, accounted for a certain amount of galvanic action. But, in the duplicate pair in question, the quality, quantity, and position of the different brands were approximately equal, hence any action occurring in one from this cause would also occur approximately in the other. It was a matter of common knowledge that when a ship was built she became a magnet, more or less permanent, at an angle corresponding with the magnetic angles of inclination of the place of manufacture. In the construction of a boiler, the position in which it was lying when *each* plate was rivetted up would determine the magnetic axis of *that* plate. If of steel, the magnetism thus induced would be more permanent than with iron, in virtue of its coercive force. Suppose a boiler, each of whose plates was a magnet in one or other direction, the result would be a magnetic battery which, as in the case of Siemens' armature and Clarke's apparatus, would set up currents of induced electricity to and from electrodes of different names. In other words, this condition of the boiler would make certain parts of itself electro-positive to certain other parts. Both of these would be in electrical contact, and both immersed in acidulated liquid. The conditions under which the most rapid oxidation of the

positive electrode would result were here fulfilled. This hypothesis seemed to him to explain several anomalies, such as the facility with which one boiler, in a pair of alleged duplicates, would take a scale, while the other rusted; that one required 80 per cent. more zinc to keep it in condition than did the other; and so on, *ad libitum*.

Mr. IRWIN spoke of the transverse strength of steel plates as at present used, compared with that of the iron plates they had at one time to work with. He also referred to what he considered the unnecessary restriction that is placed upon boiler makers by the Board of Trade, in adding to the factor of safety if the longitudinal seams of steel boilers are not crossed.

Mr. WM. CLARK said he was very pleased to have heard so instructive a paper, and one with so much novelty in it. He agreed with Mr. McKay that the joint which Mr. Rowe had brought before them was one which offered very great advantages indeed in dealing with the higher pressures now coming into use, as to meet those pressures they were all striving to get in the joints the greatest practical percentage of strength of the solid plate. At the same time, he hardly thought that Mr. Rowe gave MacColl's joint all the advantage it might possibly have, for, by scalloping the butt straps, the caulking pitch might be reduced from $6\frac{3}{4}$ in., as shown in the diagram, to the diagonal distance between the centres of the rivets in the outer and second row of rivets. While speaking of rivetting, he thought the manufacturers of boilers in this country had a very fair grievance to make against both Lloyds and the Board of Trade. The amount of trouble they had to take when designing their joints, in order to make them fit the rules of *both* parties, was unnecessary. He would be sorry if he for a moment ruffled the feelings of the representatives of Lloyds who were present; but they always got on so well together that there was not much fear of that. He, therefore, ventured to say, and he thought most of them would agree with him, that Lloyd's rules with respect to the strength of the rivets were not all they possibly might be. He suggested that if they could bring their rules into harmony with those of the Board of Trade, so that to satisfy one would be to satisfy the other, it would be a very great advantage. It was very rarely they had a paper read on boiler construction with steel plates but that great care was urged in the manipulation of the plates, or in

the process of construction they might become injured or permanently weakened. One of the misfortunes connected with the use of steel plates is that we are very rarely able to ascertain what the real cause of the failure of a plate is; but he was pretty sure of this, there could never be any difficulty in assigning some reason for it in the treatment which he maintained a boiler-plate *necessarily* received before it left the boiler yard. They knew there was no absolute precision about boiler work which is finished off the hammer. In order then to avoid the failure of plates when used for boilers of the present type, they must look to the manufacturers to improve the steel plates, and not to the boiler-maker. He had frequently heard of fractures of plates being attributed to their treatment in the boiler-yard, but he had never before heard of the fact of caulking a plate having destroyed that plate. It was not exactly so stated in the paper they had just heard read, but the strongest possible suspicion was cast upon the caulking for having destroyed the quality of a $\frac{3}{8}$ inch boiler-plate. Was it likely, he asked, that rivetters and caulkers, and others in the marine boiler trade were so ignorant as to have caused such a damage from caulking? If they looked at the constant monotony of the caulker, who was performing his avocation and repeating his simple method of caulking day by day, week by week, month by month, it was rather too much for them to believe that he could be so ignorant of so simple an art as actually to destroy a plate. He should think that in that case everything pointed to the fact that the landing edge of the plate had been broken in the setting of the landing edge to meet the regular curve of the diameter of the boiler. There might be many reasons for it; but anything rather than the caulking, certainly; and it was most probably due to the quality of the material. The landing edges formed a very important factor in the strength of a longitudinal joint; not only that, but also formed a very important factor in the possible tightness of that joint. He believed that it was not quite uncommon in some boiler-yards to trust to the rivetting machine entirely the bringing the plates together into something like the proper curve of the boiler. But there was no doubt it would be a very much better plan indeed to have their rolls so arranged that the fixed curve could be carried right up to the edge of the plate. He might say that he had been supplied with a machine which he had every confidence

would effect that purpose. In fact, the plate when it was passed through the rolls, would have a continuous curvature from one end of the plate to the other. He should only like to say, in respect to the means of circulating the water in the boiler, which Mr. Patterson saw abroad, that he would not like to be the fireman who had to circulate water in a boiler carrying twenty or thirty tons of water.

The PRESIDENT said, before asking Mr. Rowe to reply, he would like to make a few remarks. They ought to ask themselves what was the object they had to aim at in all these theories and different proportions of joints that had been brought before them that night. The answer to that question was, obviously, that it was to make the plate as thin as possible, by means of obtaining a high percentage joint, so that the thickness of plate should be increased as little as possible to compensate for the amount by which the strength of the joint fell short of the strength of the solid plate. Now, that being the case, they must, he thought, guard themselves against the danger, which possibly might exist, of trying too much to obtain a high percentage of joint, and run the risk of using a joint which it might be difficult in practice to keep tight. He thought the question of the tightness of a joint, not only in its immediate construction in the boiler-shop, but in the life of the boiler hereafter, was one which required to be very carefully watched and guarded against. With that view, he was sorry he could not endorse Mr. Rowe's approval of design in Fig. 4. He thought the butts would be very liable to leak, owing to the expansion and contraction of the boiler, and when once a leak commenced it would be very difficult to get it tight again. If the inside caulking gave way the water would pass along between the butt strap and the shell plate, and out through the joining. There was one subject in connection with the whole system of rivetting that had not been touched upon that evening, but which was well known to Mr. Clark and to many others who had made the practical construction of marine boilers their study. That was a system of plate closing the joint by which the rivet was held together by one system of pressure, and the head of the rivet closed by another and independent pressure. These two pressures might afterwards be combined, so that the double pressure held both the plate and the rivet together. This was not in operation in many places; but he thought, with regard to the very high pressures coming into use, it was one of

the most important things that had been brought forward; so that, in the actual process of rivetting, before the rivet was itself closed, the plates might be actually held together by a pressure of something like twenty-five or thirty tons, preventing them from moving.

Mr. WALLAU said, with reference to the application of zinc to boilers, some boilers gave as good results without zinc as with. He believed that by the circulation of water the effect of galvanic action was entirely avoided. He instanced a boiler which had been actually condemned on account of corrosion, but which, after it had been fitted with circulating tubes, lasted for many years. He thought the question of circulating the water was a very important one. If the feed water was properly distributed, a proper circulation took place, and there was no danger whatever, so far as he could learn. Zinc had been before the engineers for many years, but somehow or other had not been generally adopted.

Mr. ROWE, in replying to the remarks that had been made concerning his paper, said he very much regretted that so little had been said on the subject of rivetting. He would endeavour, in the few minutes at his disposal, to reply to a few of the questions asked. First, as to the statement that Mr. Foley had anticipated him in the formulæ for rivetted joints associated with the percentage curve. Although he knew that Mr. Foley had compiled a valuable series of tables for boiler designing, he was not aware that he had drawn up formulæ such as those in question. He would be glad to see Mr. Foley's formulæ to compare them with his own. In his experience, no system of joint designing was in use on the Tyne except the one referred to in his paper. Mr. Patterson asked him to explain how to design Fig. 5 type of joint. He thought if draughtsmen would only once use the formulæ they would be surprised at the ease with which MacColl's and the common type of joint could be designed. It was a little more difficult to design Fig. 5. He would explain. Assume the joint to be 85 per cent. By experience he had found that the addition of the outer row of rivets in single shear converted a double rivetted, double butt strapped joint of about 75 per cent. into a treble rivetted joint of about 85 per cent. Therefore, begin by designing a 75 per cent. joint with two rows of rivets in double shear. Having done that, and obtained the diameter and pitch of rivets, the novel feature of the

joint is obtained by pitching the outer row of rivets one and a half times the inner rows, and reducing the diameter of rivets of outer row to a mean between the plate thickness and the diameter of the rivets of centre rows. Of course a little experience would be necessary to design off-hand the most economical joint; but Mr. Patterson was as expert as he himself in designing this form of joint, and probably asked the question more for his colleagues' sakes than his own. He had also been asked to explain the meaning of obtaining a saving in the thickness of shell plates by employing rivets whose shearing resistance should be equal to the tensile resistance of the plate to which they were attached. They knew they had, when designing a joint to pass the Board of Trade, to increase the rivet section beyond the plate section in the ratio of 28 to 23. This was because the rivet strength was only $\frac{23}{28}$ of the plate strength. If, then, they increased the shearing resistance of the rivet to 28 tons, they could employ a rivet of ·9 inch diameter where they now employed a rivet of 1 inch diameter; and, taking a 75 per cent. joint as a standard of reference, a saving of 3·2 per cent. would be effected in the thickness of the shell plates. So, by the use of a superior quality of rivet steel, the same benefit could be gained as by the use of shell plates of 29 tons tensile strength instead of 28 tons. Of course it might be said—Can you get steel of that quality? Well, Mr. Smith, the courteous Manager of the Weardale Iron Works, made, some little time ago, a batch of rivets in order to test this very question; and he found that with steel possessed of about 33 tons tensile strength, its shearing resistance was about 28 tons. He himself saw a few rivets tested and could thus confirm Mr. Smith's statement. Mr. Crawford, whose observations he did not clearly hear, made some remarks concerning thin plates. He apparently doubted the statement that thin plates possessed greater tensile resistance than thick ones. For himself, he had no doubt on the subject. There was more work put into a thin plate than into a thick one; and work put into a plate meant strength. This, in a measure, had been illustrated by Mr. Crawford himself. If they suspended weights to the ends of a wire, and stretched the wire, the work put into the wire really increased its strength. He would offer Mr. Crawford a book, which he could read for himself, where the facts were stated that he had quoted. Mr. Patterson had very properly pointed out, it was possible to construct a MacColl's

joint which, whilst of the same percentage as the Tyneside joint (Fig. 5), should also have the same external pitch. The fact was, the steps followed by him in his paper were these. He first designed a common quadruple rivetted joint (Fig. 1). From Fig. 1, MacColl's joint (Fig. 2) was derived; and, having these, he gave himself the task of designing the best possible Tyneside joint (Fig. 5) to compare with them. However, having given MacColl's system every good point it is possible to advance in its favour, it is still inferior to the Tyneside in this—it lacks the Tyneside's distinguishing feature of close spaced rivets governing the landing edges of the inside caulking pitch. Now, as to Lloyd's surveyors and Board of Trade surveyors, perhaps, like other people, they occasionally required a little stirring up. So far as concerned the difficulty of complying with the regulations of both, he cordially endorsed the views of the gentlemen who had spoken on the subject. But how was the difficulty to be overcome? As a Board of Trade surveyor, he suggested that gentlemen in high positions in that and other neighbourhoods should solicit Lloyd's department to so modify their regulations, as to make them harmonise with those of the Board of Trade; and he had no doubt but that Mr. Parker, with the graciousness and tact for which he was so remarkable, would, in a generous way, respond to the invitation, and alter his rules accordingly. He hoped this would be done, and he ventured to say the profession would be all the better for it.

The PRESIDENT proposed a vote of thanks to Mr. Rowe for his paper, which was carried by acclamation.

The following communication was received from Mr. Henry R. Procter, F.C.S., dated 17th March, 1885:—

I regret that I shall be unable to avail myself of your kind invitation to attend the meeting of your Institute to-morrow. I have read the latter part of Mr. Rowe's paper with much interest, and there is no doubt he is right as to the great importance of keeping the zinc clean and securing good metallic contact with the boiler. A simple way of doing this would be to cast the zinc plate or ball on a clean "galvanized" iron rod, one end of which would be brought through the boiler shell

and secured with a check-nut. This outer end could then be filed clean and connected by a copper or iron strap with any convenient part of the boiler. Soldering or bolting *inside* the boiler will probably become oxidised and unreliable.

I do not know if the effect of amalgamating the surface of the zinc has been tried. It is very efficient in batteries in keeping the zinc clean and preventing waste from local action. The zinc is cleaned with a little dilute sulphuric acid and mercury rubbed over it with a brush. Mercury has no injurious effect on iron or steel. The cost is trifling. The action of soda on the zinc is interesting, and quite in accordance with scientific observation. In Bennett's battery caustic soda is used instead of an acid as exciting fluid, zinc oxide uniting with a strong base like soda like a weak acid.

In land boilers the use of chemicals to precipitate lime is generally found very costly from the quantity of water required ; but it is worth inquiry whether, with surface condensers, it would not pay to purify the water by chemicals and filtration before admission to the boilers, and so prevent scale altogether. This can be done by caustic soda, or mixtures of soda carbonate and quicklime, at a very moderate cost, and I cannot but think that engineers could readily overcome the mechanical difficulties.

Mr. Rowe's plan of preventing adherent incrustation by electricity supplied by a dynamo is no doubt practicable, and the slight evolution of gas would increase the production of steam, but I do not know if any inconvenience would arise from the admixture of a combustible gas with the steam.

The following communication was received from Mr. Hector MacColl, dated 23rd March, 1885 :—

I heartily concur with the view of your President, that, before working pressures of 200 to 250 lbs. can be employed, "some material modification will be necessary in the boilers at present in use ;" understanding this to mean modification of the boiler design, not merely of its constructive details. I must, therefore, express my disappointment that a paper on such an interesting subject should shrink into little more than a description and recommendation of the author's peculiar methods of arranging the longitudinal joints of cylindrical shells.

Mr. Rowe's light estimate of the difficulty in dealing with flat surfaces and with cylindrical furnaces might be correct if the cold water test were the only end in view, but the problem is a very different one, and neither flat surfaces exposed to the fire, nor circular furnaces will be easily dealt with at 250 lbs. pressure.

Pitching of Rivets.—Mr. Rowe tells us that "with plates 1 inch thick and upwards, it is probable that large pitches may be used without reducing the strength per square inch of the metal between the holes below the strength of the solid plate." Now, as 1 inch is about the minimum thickness that can be used for modern pressures, it would appear as if now, as in 1875, "the only barrier to the adoption of wide pitches lies in the real or supposed difficulty of making them tight at high pressures. It is thought, however, that with good material and workmanship the difficulty is much more imaginary than real, and that we have as yet no satisfactory knowledge of the point at which the pitch becomes too wide to make thoroughly tight work." Since these sentences were published in 1875, it has certainly been proved that there is little difficulty in making a tight 90 per cent. joint, or one having a still greater percentage of section. There is, however, a practical reason, not mentioned by Mr. Rowe, which renders the use of very high percentages inexpedient. If, for example, we adopted solid rolled rings for boiler shells, the section would be 100 per cent.; but it is evident that we could not drill a hole for a water-space stay, for a mounting, nor even for a lagging screw, nor could a patch of corrosion occur, without reducing the strength of the entire structure. Our rolled rings would, therefore, have to be credited with 10 per cent., 15 per cent., or 20 per cent. less section, to allow for these necessary piercings; and this consideration, therefore, bars the use of joints having much more than 80 per cent. section.

Percentage Curve.—The sole value of this curve appears to lie in its presenting a graphic view of the problem to minds unaccustomed to the subject. To others, there is nothing either new or appalling in the fact that the ratio of pitch to diameter of rivet is, with 90 per cent. section, double what it is with 80 per cent. If the curve really has, as Mr. Rowe suggests, such an effect "as to point to the hopelessness of the attempt to obtain, by ordinary methods, a joint possessed of 90 per cent. section," then it cannot be too quickly put out of sight and out of mind.

The new formulæ given by Mr. Rowe are distinct improvements, deserving our best thanks, but the order of designing a joint would hardly be that described by Mr. Rowe, except perhaps in a drawing office where high percentages presented correspondingly great difficulties. Using Mr. Rowe's formula, in place of an equally effective but less neat method, the order would be as follows:—

1st—Determine upon double butt straps as giving thinnest shell.

2nd—Determine the percentage to be adopted.

3rd—Calculate the thickness of shell.

4th—Fix the size of rivet from any personal factor thought proper; then

R = ratio of pitch to diameter of rivet,
t = thickness of shell plating,
d = diameter of rivet in inches,
n = number of rivets per pitch,
P = pitch of rivets in inches.

It is required to construct a 90 per cent. joint, with plate 1 inch thick.

$$\left.\begin{array}{l} \mathrm{R} = 10 \\ t = 1 \text{ inch} \\ d = 1 \text{ inch} \\ \mathrm{P} = 10 \text{ inch} \end{array}\right\} n = \frac{(10 - 1) \times 1}{1{\cdot}129 \times 1} = \frac{9}{1{\cdot}129} = 8 \text{ rivets.}$$

All that remains to be done is to arrange the eight rivets in 10 inches pitch, as experience or judgment may suggest; from which it would appear that the proportioning of a 90 per cent. joint is not so formidable a matter after all.

The difference between the order discussed and illustrated by Mr. Rowe and that laid down here, is that the former fixes beforehand the number of rivets, which is a matter of no moment, and leaves for after-calculation the size of rivet, a matter of the utmost importance to know beforehand, while the latter reverses these positions.

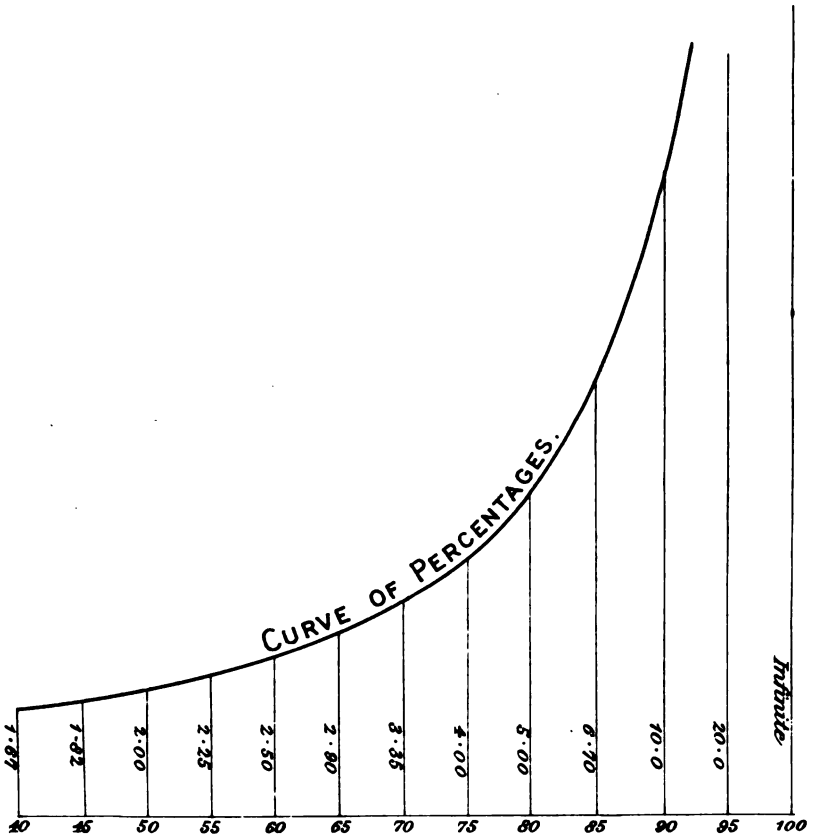
Riveting.—I regret that Mr. Rowe should have thought it necessary to call a particular joint by my name, and the more so that the joint he has illustrated and criticised is not to be found in the paper from which he appears to quote. He is quite right in saying that "it is impossible by any system of rivetting yet put forward to construct a joint in the

mode known as MacColl's which shall possess a greater percentage of joint than can be obtained by the old system." It is not quite clear what Mr. Rowe means by "the old system;" for, so far as I know, there is only one "system" in rivetted joints by which a high percentage can be got; and that is by making the rivet area correspond to the desired percentage—no "system," old or new, can get over that. On the other hand, it is possible to arrange the rivet area effectively and economically, or to arrange it uselessly and wastefully; and by this I propose to measure Mr. Rowe's proposals.

In Figs. 3, 4, and 5, proposed by Mr. Rowe, there is a very obvious want of economy in the fact that in each case he has two sizes of rivets, so that two sizes of drills must be used in making the holes, and two sizes of rivets in filling them. Fig. 3 has the still more serious economical defect, that while it has more labour and material in the joint, its value, by the Board of Trade rules, is only $\frac{83{\cdot}3}{5{\cdot}15} = 16{\cdot}17$, the value of No. 1 and 2 being $\frac{85{\cdot}1}{5} = 17{\cdot}02$. In other words, where the Board of Trade would give a pressure of 170 lbs. for Fig. 1 or 2, they would only give 161 lbs. for Fig. 3. Or put another way—Figs. 1 and 2 are $5\frac{1}{2}$ per cent. better than Fig. 3.

Fig. 4 is not worthy of serious discussion; for while it possesses grave disadvantages, as compared with an ordinary double butt strapped joint, its cost would be enormous. If "corrosion follows the caulking tool," we might expect unusual corrosion with No. 4, on account of the free and generous use of the caulking tool it would require. No. 5 is certainly the best of the three, and would be still better if the inside butt strap were widened to be laid hold of by the rivets C. As it is, it is impossible that the strains could be evenly distributed in a hermaphrodite joint having some rivets in single and others in double shear.

In conclusion, Mr. Rowe has taken great pains, and has shown considerable skill, in avoiding plain straightforward methods of making longitudinal joints in cylindrical shells; but, in my opinion, he has entirely failed to show how our present pressures may be increased by one single grain.



NOTE.—The dimensions of ordinates are the ratios between the pitches of rivets and the diameter of rivets. The percentages are shown on base line.

FORMULÆ

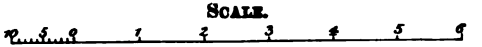
To construct joints of any required percentages with equal sections of plate and rivet. Allowance has been made for inferiority of rivet to resist shearing stress.

$$\frac{(R - 1) \times t}{\cdot 645 \times N} = d \text{ when rivet is in single shear.}$$

$$\frac{(R - 1) \times t}{1 \cdot 129 \times N} = d \text{ when rivet is in double shear.}$$

When R = ordinates of curve,
t = thickness of shell plate in inches,
N = number of rows of rivets,
d = diameter of rivet in inches,
And $d \times R$ = pitch of rivets.

SCALE.



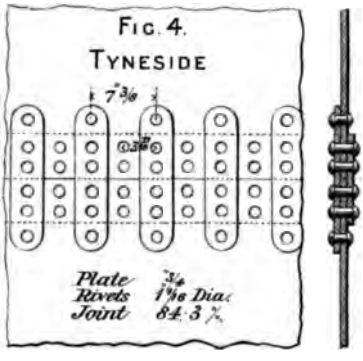


Fig. 4.
Tyneside
7 3/8
Plate 3/4
Rivets 1 1/16 Dia.
Joint 84·3 %

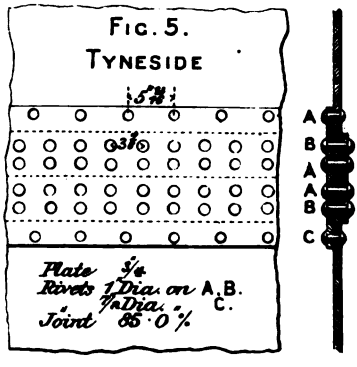


Fig. 5.
Tyneside
A
B
A
A
B
C
Plate 3/4
Rivets 1 Dia. on A, B.
7/8 Dia. " C.
Joint 85·0 %

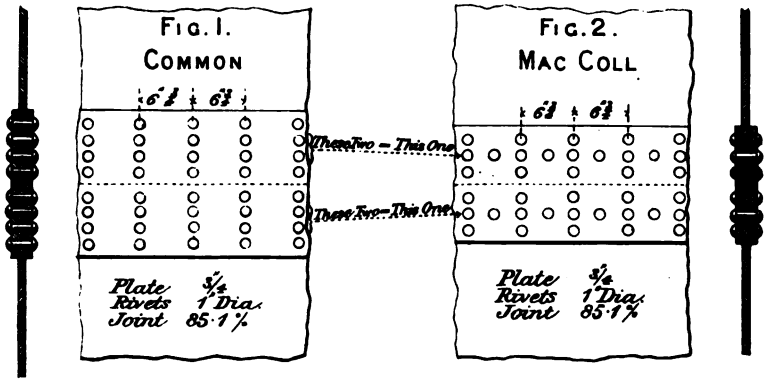


Fig. 1.
Common
6 1/2
6 1/2
Plate 3/4
Rivets 1 Dia.
Joint 85·1 %
Fig. 2.
Mac Coll
6 1/2
6 1/2
Plate 3/4
Rivets 1 Dia.
Joint 85·1 %

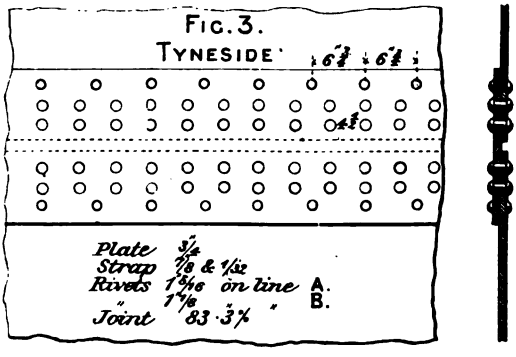
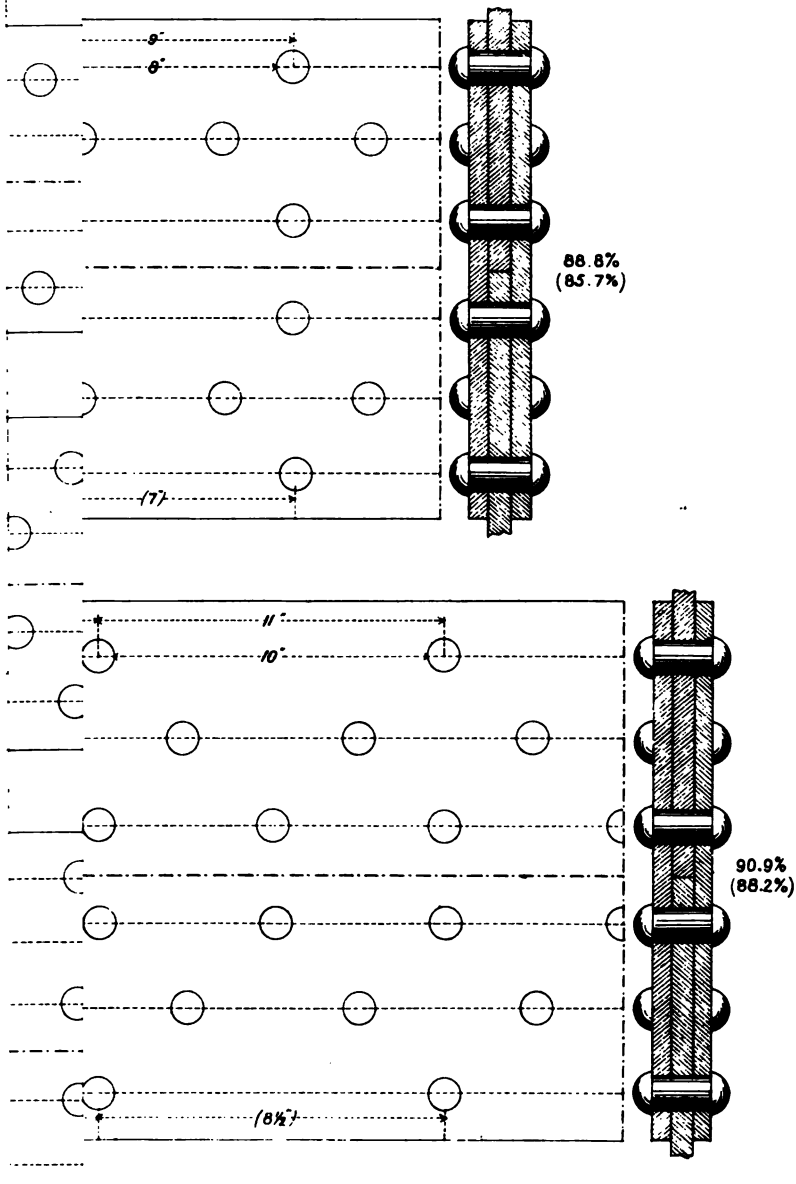


Fig. 3.
Tyneside
6 1/2
6 1/2
Plate 3/4
Strap 7/8 & 1/2
Rivets 1 3/16 on line A.
1 1/16 " B.
Joint 83·3 %

Double rivetted section in plate & rivets 1" dia.r } Iron



Ant. Reid, Lith. Newcastle.

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NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.

FIRST SESSION, 1884–85.

GENERAL MEETING IN THE LECTURE HALL OF THE LITERARY AND PHILOSOPHICAL SOCIETY, NEWCASTLE-UPON-TYNE, WEDNESDAY, APRIL 1ST, 1885.

F. C. MARSHALL, ESQ., VICE-PRESIDENT, IN THE CHAIR.

ON TRIPLE EXPANSION ENGINES.

BY ALEXANDER TAYLOR.

IN reading this paper on Triple Expansion Engines, the writer will endeavour to give only a few practical results he has noted, and will take for granted that this meeting is well acquainted with the ordinarily accepted theory of the expansive force and economical use of steam. But by way of keeping clearly before our minds the principles involved, he will now and again refer to Plate XVII., which shows graphically the ratio between the power expended and the power utilised for various pressures. The power expended is calculated for a feed-water temperature of 122 degrees. The writer will now give a practical illustration of the advantages of 150 lbs. pressure, and triple expansion, over the ordinary compound engine and 100 lbs. pressure. Two steamers were built, one after the other, by the same builder, from one model, and were in all respects identical, except the propelling machinery. The first has two cylinders 23 inches and 46 inches diameter with 33 inches stroke, and a boiler 12 feet 9 inches diameter and 10 feet 6 inches long, having 1,649 square feet of heating surface and 100 lbs. working pressure. This is one of the very best examples of the ordinary type of compound engines. The second has a "triple expansion engine," the cylinders being 14¼, 20¼, and 40 inches diameter respectively, each having 33 inches stroke. The boiler is 11 feet 8 inches diameter and 10 feet long, with 1,392 square feet of

heating surface and 150 lbs. working pressure. The propellers for these steamers are each 12 feet diameter, and are the same in form, but, the ordinary compound has 15½ feet pitch, and 36½ square feet of surface, while the other has 14 feet pitch and 35 square feet of surface. The crank and propeller shafts of the ordinary compound engine are 9 inches diameter, while those of the triple expansion engine are 8¼. The first went to sea in October, 1881, and the second in March, 1882. After these vessels had run for about twelve months the writer had extracts taken from the logbooks of each, showing the number of hours under steam, the distances run measured on the charts, and, when practicable, checked by tables of distances. An account of bunker coals has also been taken from the owners' books. The results are as given in the table below. The second line for the two-cylinder engine is given, in order to compare with the three-cylinder engine during the same period of the year. In it we have, for the two-cylinder engine, particulars from March 18th to December 17th, 1882; and for the three-cylinder engine we have from March 11th to December 31st of the same year. The vessels were practically in the same trade, and therefore must have had much the same weather. And as they had the same freeboard, the displacements may be taken as equal throughout.

	Hours steamed.	Knots steamed.	Bunker coal used.	Mean speed.	Mean consumption.	Percentage of time steamed.
			Tons.	Knots per hour.	Tons per day.	
TWO-CYLINDER ENGINE—						
From 18th Oct., 1881, to 17th Dec., 1882...	4,237	32,964	1,531·25	7·77	8·66	41
From 18th March, 1882, to 17th Dec., 1882...	3,061	23,754	1,121·25	7·76	8·78	46
THREE-CYLINDER ENGINE—						
From 11th March, 1882, to 31st Dec., 1882 ...	3,365	26,545	1,014·75	7·89	7·23	47

You will observe that the three-cylinder engine has rather a greater percentage of its time under steam than the two-cylinder engine, while

the speed is also slightly in its favour, and the consumption is considerably in its favour. Allowing the speed to be equal, the saving in the total coal is 17·6 per cent. for the same time of year. As in each case the coal consumed by the donkey boiler in mooring the vessel, discharging cargoes, &c., is included; we may therefore allow 0·25 tons per day for this work, and if this quarter ton is taken off each, the saving would then be 18·1 per cent. You will observe that 18 per cent. saving of coal is much in excess of the theoretical efficiency given by our efficiency curve in Plate XVII.; but perhaps some of our members may be able to throw new light upon this point.

Most of you will have seen Mr. McFarlane Gray's letter in *Engineering*, of February 20th last, where he says, "I have now to announce that the outcome of my continued investigations is, that the second law of thermodynamics is not a law of nature. The theoretical efficiency of heat in the cycle steam engine is greater than is expressed by temperature range divided by absolute temperature, and this excess increases as the higher temperature increases. This accounts for the unexpectedly high efficiency of the triple expansion engine."

Neither the captains nor engineers of these vessels were aware that the logbooks were to be examined for any such purpose as the above; and the coal supplied to each steamer may be considered ordinary east coast coal. In fact, it is to be clearly understood that the vessels were not run for any competitive trial, but in the usual way of business, and practically in the same trades.

The above result fully confirms a sound practical comparative test which happened in the following manner:—These steamers were loaded and bunkered from one colliery, and sailed from the Tyne the same tide, each bound for Oporto. The three-cylinder ship was one hour the sooner to Dover, and four and a half hours the sooner to Oporto bar, showing that the three-cylinder ship is not the slower. From Oporto the latter went to Pomeron, and loaded home. The other went to Bilbao, and loaded home. The respective distances are as 3,030 to 2,596, and the coal consumed was as 100 to 105, showing a saving of coal of 18¾ per cent., irrespective of extra speed. Plate XX. shows a blade of each propeller of these ships, the meeting can decide for itself as to whether the difference in propellers can in any way account for the difference in consumption. Lately we have been

told of triple expansion engines using 30 to 40 per cent. less coal than in the ordinary compound engine; but most probably this will be difficult to prove.

Several questions naturally arise here:—1st. It may be asked why (if the foregoing be correct) was such an important saving not grasped and acted upon before? 2nd. Why cannot this saving be obtained in one or two cylinders, instead of using three? 3rd. Why was not the Perkins engine a complete success, instead of the failure it has been in the marine world, as it had three cylinders and much greater pressure than any above named? The writer will now try to give a satisfactory answer to each of these questions.

1st.—Why was such an important saving not grasped and acted upon before? In answer, the writer may say that the economy of high-pressure steam has been known nearly as long as the steam engine itself; but he fears that the majority of our manufacturers and practical friends, instead of examining the subject with a view to the improvement of the engine, have been too much inclined to stick to old patterns and well-known practice, and to magnify the excessive wear and tear which they believed would take place, along with other supposed disadvantages attending the use of high pressure; and most of the attempts to deal with high pressure were tried under exceptionally unfavourable circumstances, such as peculiar boilers or engines, so that it was not to be wondered at that they failed, and each failure strengthened our conservative brethren, and delayed the introduction of high pressures. Without doubt their greatest difficulties were in the boiler, brought about, probably, by ignorance and want of care and attention to its requirements and construction. The very fact that there have been, and now are many patent boilers in the market, shows how much thought has been given to the boiler, and how important a question it is. The writer has seen taken out of steamers, within the last few years, at least twelve different patent boilers, which were all, more or less, designed with the expectation that they would supersede the ordinary cylindrical multitubular boiler, for carrying high pressure, but which, after receiving full trial, at a great expense, have only resulted in adding to our experience, by teaching us what to avoid, and in throwing us back upon the ordinary multitubular boiler, which still stands alone, more valued every day; and

now, when reasonable care and attention are bestowed upon it, both in the drawing office and the workshop, we may safely say the ordinary boiler is not only the very best we have, but it meets all the practical requirements of a high pressure marine boiler. Let us look for a moment at what we require from a marine boiler. First, it must contain in a small shell a large amount of heating surface, and a fair quantity of water and steam space; it must be easily and quickly accessible in every part; it must also be easily cleaned, and must contain a large space in which mud and other foreign matter may deposit harmlessly; and it must have the fire and water so placed, as to induce the least possible priming. These are all vital points, which few patent boilers satisfy. Without doubt, the boiler question was the most serious, and the advance to higher pressures was delayed principally through it.

We now come to our second question: Why cannot high pressure steam be as economically used in one or two cylinders as in three? This opens up a wide field for discussion, but you will perhaps allow the writer to answer it briefly, thus—"one cylinder is all that is necessary, where an earlier cut off than a half is not required, as in this case the temperatures of the cylinder are never very much higher or lower than the mean, and the steam can be admitted and exhausted by the common slide without the aid of complicated valves and gear; but when, in one cylinder, steam at about 150 lbs. pressure, having a temperature of 366 degrees, is to be expanded down to 7 lbs. absolute, and exhausted at 3·7 lbs. absolute, the latter of which has a temperature of 149 degrees, we get in the cylinder a range of temperature equal to 217 degrees. That is, the cylinder ports are one instant swept by steam 217 degrees hotter than the steam they are swept by in the next instant, and the steam in the slide exhaust port is 217 degrees colder than the steam outside the slide." Under such circumstances, need we wonder if the slide and cylinder faces get torn and destroyed, or if they cut up and crack. The evil is further aggravated by the slide and ports having to be large enough to permit the low pressure steam to travel at a reasonable rate. The stress upon such a slide at times is simply enormous; but this is not all. The steam in the steam chest is 217 degrees hotter than the exhaust steam, consequently, the condensation on the back of the slide, and in the ports

and cylinder, must be considerable. There is still another evil to be faced, namely, if the steam at 150 lbs. pressure is to be used and expanded in one cylinder only, then the piston rods, connecting rods, cranks, and all the parts subject momentarily to this enormous stress must be strong in proportion, and we all know what shocks and jars, all early cut off engines are subject to; and, as before stated, the slide and cylinder face must be as large as if only required for the lowest pressure. It was to overcome most of the above difficulties that the compound engine was tried. Here are diagrams (Plate XVIII., Figures 1 and 2) showing steam of 165 lbs. pressure expanded down, as described above, but in two cylinders, and the cut off is necessarily so early that it may be termed a "break down" cut off. The range of temperature in the high pressure cylinder is 104 degrees, and in the low pressure 144 degrees, both an excess of what is found advisable.

We now take our third question, and it is most important and absolutely necessary that we should satisfy ourselves as to the cause of failure of the Perkins engine to fulfil the demands made upon it by marine work, as it certainly was the boldest and most original attempt made in our time. The writer will, therefore, endeavour to answer the third question, namely:—Why was not the Perkins engine a complete success, instead of the failure it has been in the marine world, for it had three cylinders and much greater pressure than any he has named? First, allow him to say, that the Perkins boiler may be the best we have for such pressures as 500 lbs., provided always that it is supplied with absolutely pure water. But, in the writer's opinion, it lacks a proper amount of water, and steam space, to be a good boiler for general purposes, and to stand the rough usage and irregular feed and firing to which boilers are subjected. On account of its exceptionally limited steam and water space, the firing requires to be almost absolutely regular; otherwise, the pressure is subject to great variation. Mr. Perkins states in his paper, that the "Emily's" pressure could be reduced from 500 lbs. to 260 lbs. in one and a half minutes. The feed must also be exceptionally regular, as Mr. Perkins states that he got 250 indicated horse-power from a boiler containing only 300 gallons of water, so that all the water must have passed through the boiler within an hour; while a boiler of the ordinary circular multi-

tubular type, to indicate the same horse-power, would contain about 3,500 gallons of water, or more than eleven times as much as the Perkins boiler. The extra water and steam in an ordinary boiler, acts just the same as a huge spring or fly wheel, which can store up or give out sufficient power to keep the boiler pressure nearly uniform under very irregular firing or feed; and all boilers containing little water and steam space are at a disadvantage in this respect. Of course, it is granted that the larger we make the boiler, and the more water we carry, the less cargo will be carried by the ship. The writer saw one Perkins boiler (which, by the way, is as near perfect as may be as a pure water boiler), practically ruined by the leakage of a condenser tube. We may take it that the boiler which can be rendered useless by damage to a condenser tube, or other such trifle, is not the boiler to send to sea; but the writer is not prepared to say that it may not be re-designed and so improved, as to meet all vital requirements, and yet keep its character for lightness and strength.

We now come to the engine—and the writer is sorry to say he has a worse opinion of the Perkins engine, than of the boiler. Here is a sketch of the cylinders (Plate XIX.) showing a most expensive and complicated internal arrangement of heating pipes; and outside, the cylinders are again protected from cooling, by a double iron casing, filled with vegetable charcoal; but if you will follow the writer, he will show how the vital internal cylinder surfaces are neglected or misused. The steam from the boiler only enters the top end of the first or small cylinder; in fact, the high pressure piston is a ram with the piston rings at the end, and below the piston rings, the ram must of necessity only fit the cylinder loosely, leaving a small space between the ram and the cylinder barrel. Now, when the high pressure engine comes near the bottom of its stroke, and exhausts, the steam travels into the bottom of the lower cylinder, and drives the lower piston up to the top of its stroke, the steam is then exhausted from the bottom of the lower cylinder, and passes into the space above the top of the piston, and also into the chest of the low pressure cylinder; in fact, the low pressure chest and the space above the second piston are in free communication, with the result, that the exhaust steam from the second cylinder surrounds the half of the high pressure cylinder and the whole of the ram, and travels up between the high pressure ram and

the high pressure cylinder; and all that there is between it and the steam direct from the boiler, is the high pressure piston packing rings. Now you will easily see that when the high pressure piston has descended a few inches down the cylinder, the entering steam having a temperature of 439 degrees, due to 360 lbs., comes in contact with a surface which the instant before was surrounded by steam at about 230 degrees, due to 6 lbs. pressure, or a difference of 209 degrees, and it is not assisted by any cushioning worth noticing, and the high pressure exhaust is 180 degrees lower than the boiler heat, as the cards themselves show; therefore, the ports, valves, and cylinder, must feel this lowering of temperature at every stroke; or, we may take it that the mean temperature of the high pressure cylinder, ram, and ports will not exceed 340 degrees, giving a difference of 100 degrees at least between them and the entering steam. The writer attaches great importance to this temperature question, and to impress its importance upon you, will only mention this fact, namely, that the mean temperature of the sea is about 68 degrees, and the exhaust from the ordinary low pressure cylinder into the condenser is usually about 145 degrees, or a difference of only 77 degrees between the circulating entering water and the exhaust steam; and yet we know how rapidly the steam is condensed even on the greasy, dirty tubes, whose mean temperature can only be about 39 degrees less than the entering exhaust steam. And yet, Mr. Perkins allows a difference of 209 degrees in his high pressure cylinder. Need we wonder that the Perkins engine generally shows a loss of about 150 lbs. pressure, between the boiler and the initial pressure recorded on the cards, when we find the high pressure cylinder such a first-class surface condenser? These cards (Plate XVIII., Figures 3, 4, and 5) were copied from Bramwell's report on the "Anthracite," and fully bear out the above facts; but they show a loss of 170 lbs. between the boiler and engine.

The writer will now try to show the advantages which the triple expansion engine has over all others using steam of 150 lbs. pressure. First, here (Plate XVIII., Figures 6, 7, and 8) we have a set of cards from a triple expansion engine. You will notice that the high-pressure card shows a loss of between 8 and 10 lbs. of steam, between it and the boiler, which is about the usual proportion; the high-pressure exhaust lowest point shows a pressure of 57 lbs. There is consequently only

a range of 60 degrees in this cylinder. Now, taking the second card, we find a range of temperature equal only to 67 degrees, and in the low-pressure cylinder we have the usual range of about 105 degrees. You will notice here that the range of temperature is small, compared to the range in the Perkins engine, or even as compared with the ordinary compound engine, with 100 lbs. pressure.

In designing a triple expansion engine, we at once get out of the ordinary proportions of heating and cooling surface, steam space, and sizes of shafts and pumps, to both the nominal and indicated horse-power. Extremely vague ideas are entertained regarding these points. We should remember that we have still the same natural draft in our furnaces, which only permits us to burn the usual amount of coal per square foot of grate, and we must have the usual heat in the funnel in order to obtain this natural draft; we also have the ordinary kind of heating surface to take up the heat, therefore the conditions are not changed, so far as the coal, and the heat imparting powers are concerned. Neither has the heating surface been changed. If we now examine the other end—that is, the low-pressure cylinder; —we find there the same terminal and back pressure as in the ordinary compound engine; therefore the steam in the low-pressure cylinder is unchanged; for the same weight of steam passes through the low-pressure cylinder at each stroke, and carries the same quantity of heat to the condenser, as before; and, as a consequence, the same heating and cooling surface, and pumps, will be required for a given low-pressure cylinder, no matter what boiler pressure, or what number of cylinders may be used. But with steam increased to 150 lbs. pressure, and having added another high-pressure cylinder to the engine, we can take considerably more work out of the steam. But in increasing the boiler pressure, we can decrease the size of the boiler shell, for we have practically doubled the weight of steam in each cubic foot; and as we have also a high-pressure cylinder, of about one-half the former capacity, to supply with steam from the boiler, we get a greater steadiness in the steam, and on this account, we can reduce the boiler steam-space considerably; or, in other words, we can put a given amount of heating surface into a smaller shell. For all practical purposes, we may reckon upon getting an indicated horse-power from three square feet of heating surface, under such ordinary circumstances

as obtain on trial trips in the mercantile marine. A successful triple expansion engine with a boiler pressure of 150 lbs. is now an accomplished fact; because we can make the invaluable ordinary boiler to stand the necessary pressure, and yet get ample space for steam, water, and dirt; and by designing the engine so that each cylinder shall be kept as near to its mean temperature and pressure as possible, we reduce the wear and tear to reasonable compass, because the writer believes the wear and tear and waste in cylinders and slides is very much governed by varying temperatures. The size of the shafting will also require reconsideration; and last, but not least, the slide-valve, and the manner of driving it, must go through a searching examination:—unless we are content to go on with the ordinary slide-valve and link motion, to which the writer sees no objection. Asbestos boiler gauge-cocks appear to answer well. It appears doubtful whether a metallic packing is yet invented, that will give better all round results, than the ordinary canvas and asbestos packing, for slide and piston rods. The writer has seen no serious defect in the triple expansion engine, to counter-balance its enormous saving in coal; and when all the small details which demand attention on account of increased pressure or temperature have been carefully provided for, the writer is satisfied the triple expansion engine will be, in durability, equal to the ordinary compound engine, while he is also sure that the boiler will last longer than its lower pressure brother, if the Board of Trade or Lloyds do not reduce their factor of safety.

The relative cost of an ordinary compound and triple expansion engine, to indicate the same horse-power, the writer has no direct means of giving; but he is quite sure that the triple expansion engine should be made at the least cost. For the following reasons, viz:—

The boiler capacities may be as	80· to 100
Heating surface as	85· to 100
Cooling surface as	85· to 100
Capacity of pumps as	85· to 100

The figures being the reduced proportions which may be adopted for the triple expansion engine. The main shafting may also be reduced.

The boiler for the triple expansion engine will be about 5 per cent. less weight than the ordinary boiler, and its water will be about 25

per cent. less. The stop valves and safety valves can be a trifle smaller, but this may be set against the cost of more careful jointing, etc. The steam and feed pipes will also be a trifle smaller, but the increased thickness required will perhaps make them equal in weight. The writer might here say that he has invariably used wrought iron main steam pipes for 150 lbs. pressure, and so far without repairs.

THE CHAIRMAN, in rising to open the discussion, said it might clear the way towards a proper understanding if Mr. Taylor would tell them, before the discussion began, whether his remarks concerning the triple expansion engine applied to the triplex engine, that was, three cylinders with three separate cranks, or to an engine having only two cranks but three cylinders, two of which were placed tandem fashion.

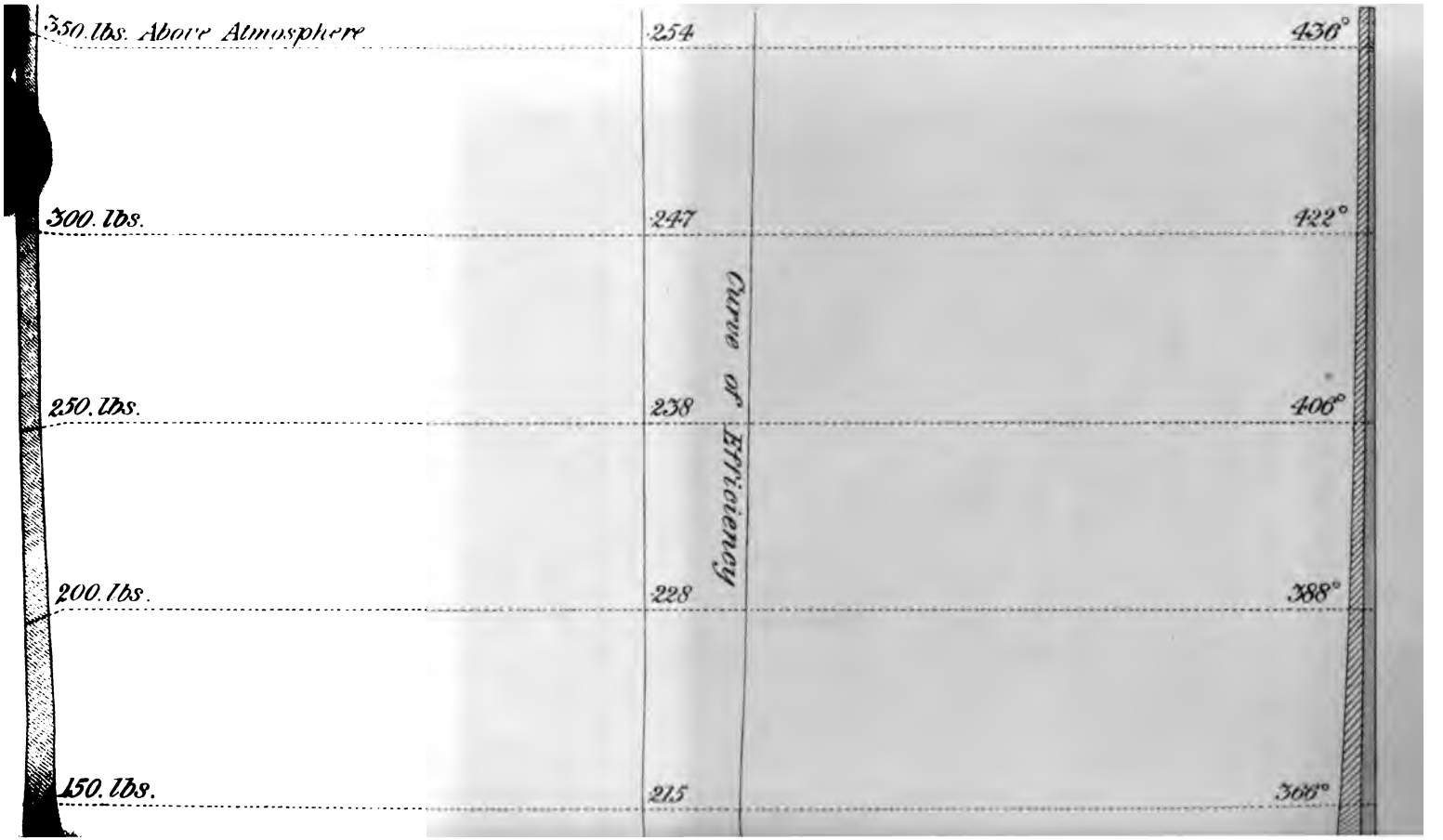
Mr. TAYLOR, in answer, said his remarks especially referred to engines of his own design with two cranks instead of three. For many reasons, he did not wish to bring the crank question forward.

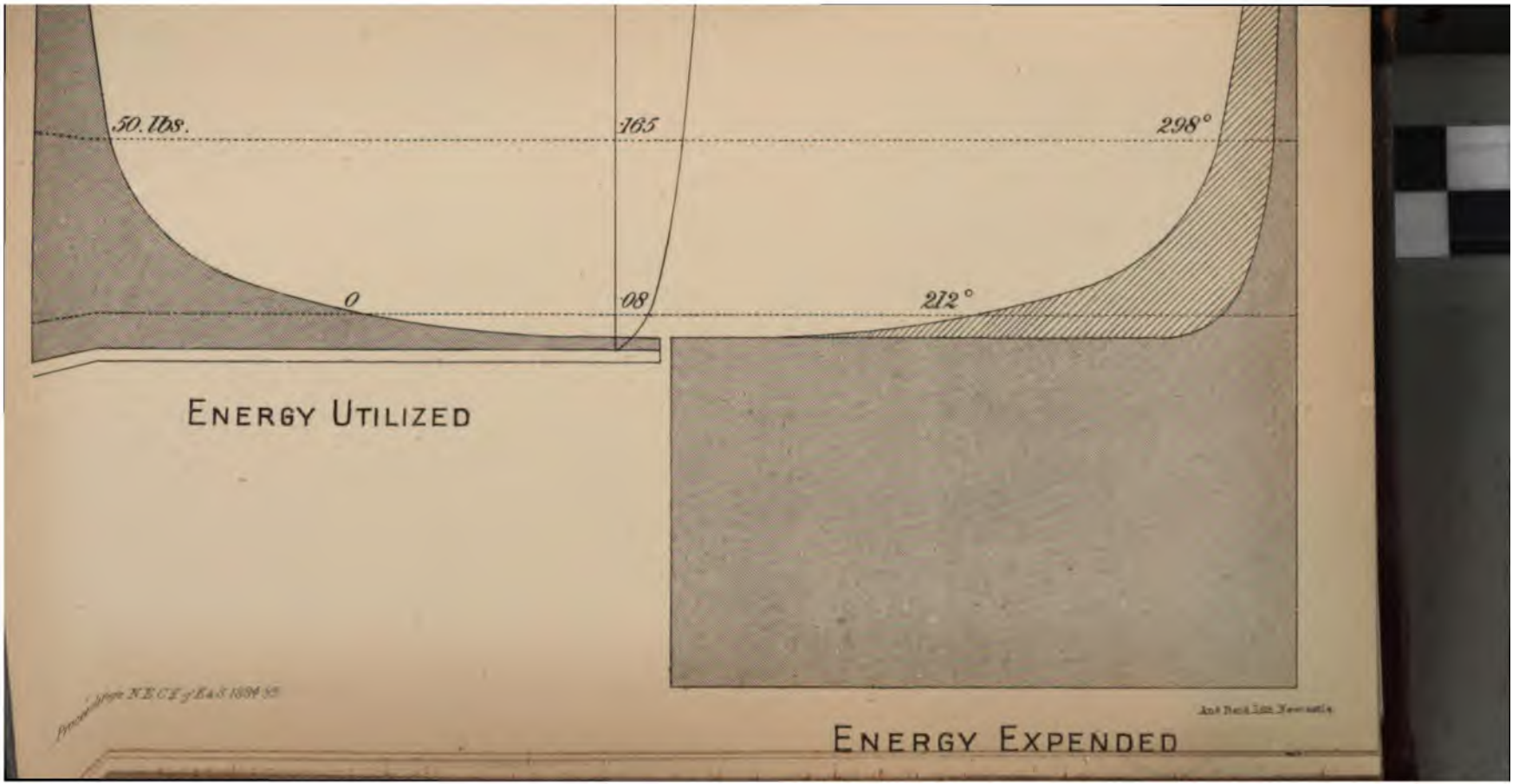
Mr. B. G. NICHOL said he could not conceive of a subject in engineering science of more interest or more importance to engineers, shipbuilders, and shipowners, than the subject under discussion. He thought they owed a deep debt of gratitude to Mr. Taylor for his foresight and skill, and for the persistence with which he had advocated, and caused to be adopted, the triple-cylinder engine; because, from the data given to them, it evidently possessed a higher economy than the ordinary two-cylinder compound engine. He felt very much interested in that particular paper, because, eleven years ago (in 1874), he had a great deal to do with a pair of three-cylinder triple expansive engines, which were constructed by the Ouseburn Engine Works Company. The results obtained from the engine when on trial appeared so good that at that time he could not believe them; but after the evidence that Mr. Taylor had brought forward as to the working of his engines, he had come to the conclusion that the data then obtained were perfectly correct. At the time, it was his opinion (although instructions were given to measure the coal) that a considerable quantity of unmeasured fuel had found its way into the furnaces, and he therefore did not attach the importance to those

trials which they evidently deserved. These engines were fitted in the S.S. "Sexta," the cylinders were, respectively, of 11, 17, and 24 inches diameter, with a stroke of 18 inches, and working on to three cranks placed at an angle of 120 degrees to each other. The boiler was constructed for a working pressure of 120 lbs., and possessed an unusually large amount of heating surface compared with the work to be done. He had made the following analysis of some of Mr. Taylor's results, and also of results from that very engine:—

	Mr. Taylor's Two-cylinder Two-crank Ordinary Compound Engine.	Mr. Taylor's Three-cylinder Two-crank Triple Expansion Engine.	S.S. "Sexta" Three-cylinder Three-crank Triple Expansion Engine.
Indicated horse-power	379	400	101·4
Lbs. of coal per I.H.P. per hour ...	2·164	1·6875	1·518
Heating surface per I.H.P. ...	4·351	3·68	6·61
Lbs. of water evaporated per lb. of coal per hour	8·565	8·515	9·61
Lbs. of steam used per I.H.P. per hour	18·5	14·369	14·59

In the above table, had they considered, as Mr. Taylor had done, engine and boiler all away together, and simply compared the one result with the other, when dealing with the values of boilers and engines, they must have come to a very erroneous conclusion, as the "Sexta's" consumption was only a little over $1\frac{1}{2}$ lbs. per indicated horse-power per hour, as against a little over $2\frac{1}{8}$ lbs. in the case of the two-cylinder engine, and in Mr. Taylor's three-cylinder double-crank engine the consumption was $1\frac{13}{16}$ lbs. per indicated horse power per hour, they must come to the conclusion that the "Sexta's" engine was the most economical of the three. He believed it was absolutely necessary (and the large proportion of boiler surface pointed this out) to separate the engine from the boiler and estimate the relative efficiency of each. In the "Sexta's" engine there was a very large ratio of heating surface to indicated horse power, and necessarily, with the much larger surface, they had a considerably greater quantity of water evaporated per pound of coal. But when they came to compare and measure the weight of steam used per indicated horse-power, they found that in the two-cylinder engine it was $18\frac{1}{2}$ lbs., in Mr. Taylor's three-cylinder engine 14·369 lbs., and in the "Sexta's" engine 14·59 lbs., or the

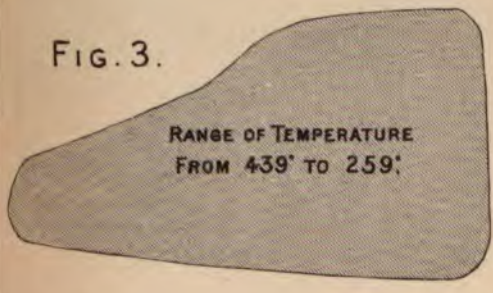

350. lbs. Above Atmosphere
254
436°
300. lbs.
247
422°
250. lbs.
238
406°
200. lbs.
228
388°
150. lbs.
215
368°
Curve of Efficiency


50. 168.
165
298°
0
68
212°
ENERGY UTILIZED
ENERGY EXPENDED

Boiler Pressure

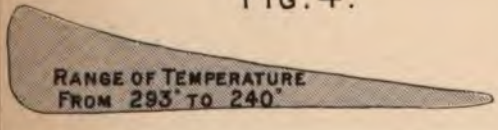
S.S. Anthracite.

Fig. 3.



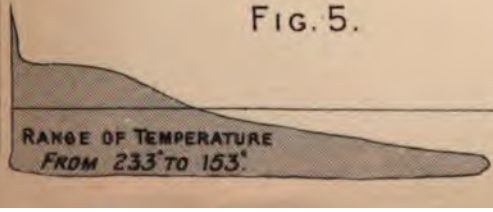
Pressure–lbs. per Square inch.	Temperature
340	433·3
320	427·9
300	422·1
280	416·1
260	409·6
240	402·8
220	396·0
200	388·0
180	379·2
160	370·8
140	361·0
120	350·1
100	338·0
80	324·1
60	307·5
40	287·1
20	259·3
0	212·0

Fig. 4.



lbs. per Sq. in.	Temperature
60	307·5
50	298·0
40	287·1
30	274·4
20	259·3
10	240·1
0	212·0

Fig. 5.



lbs. per Sq. in.	Temperature
15	230·4
10	240·1
5	228·0
0	212·0
5	193·3
10	162·3
15	

LE-OF-DURSEY.

R PRESSURE

FIG. 6.

Scale 1/120

CORLISS LAND ENGINE.

BOILER PRESSURE

FIG. 1.

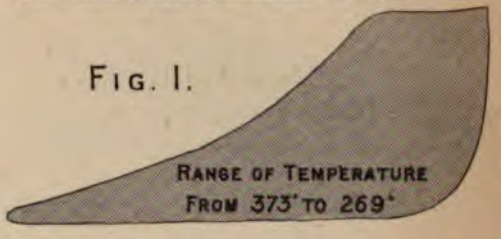
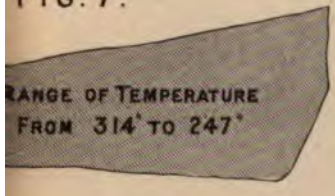


FIG. 7.

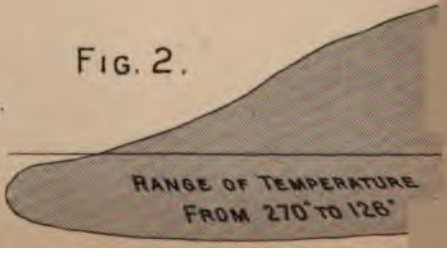


Scale 1/60

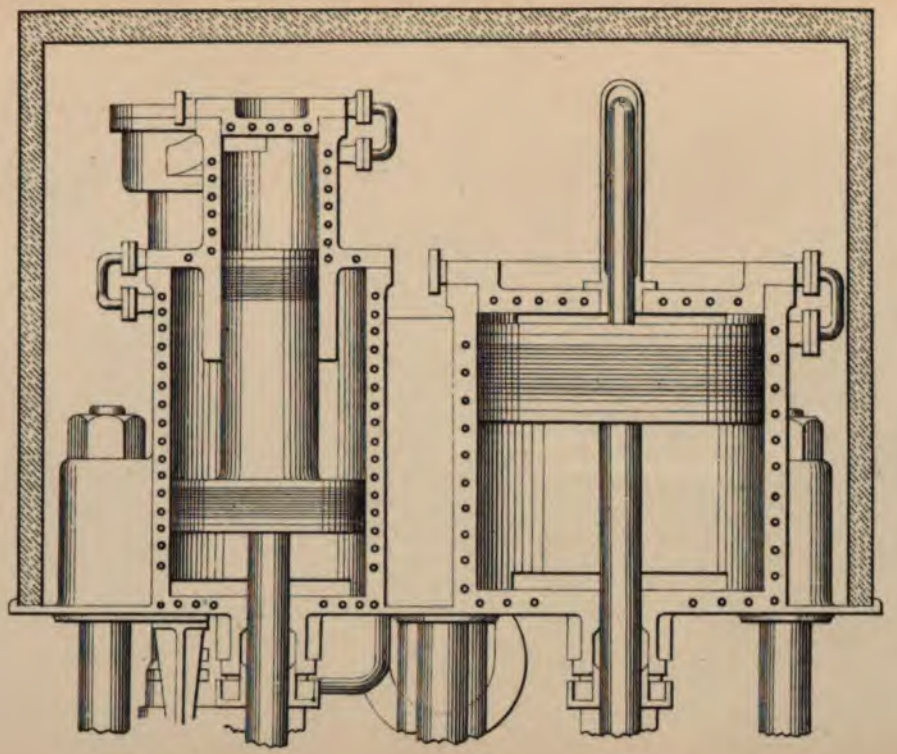
FIG. 8.

Scale 1/30

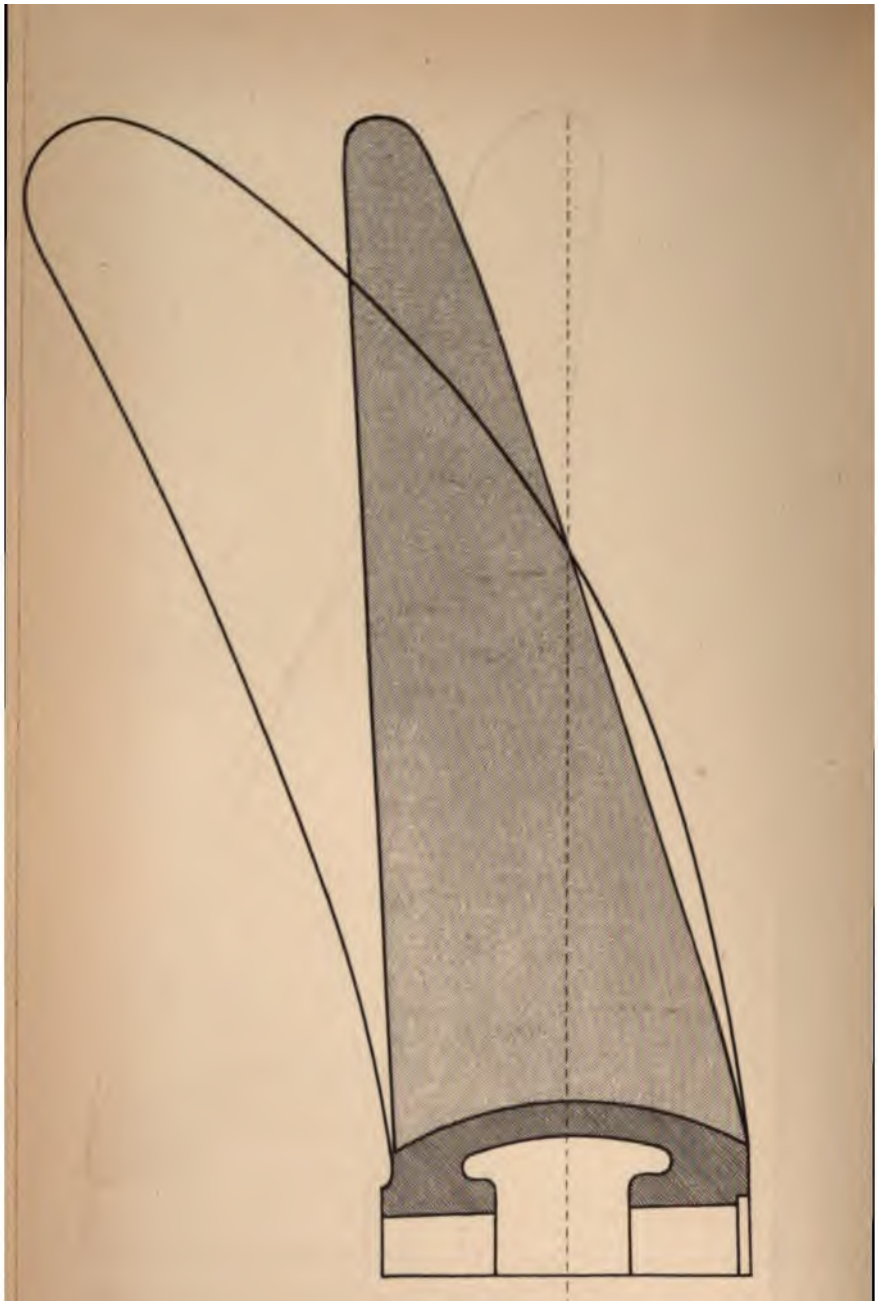
FIG. 2.



PERKIN'S ENGINE

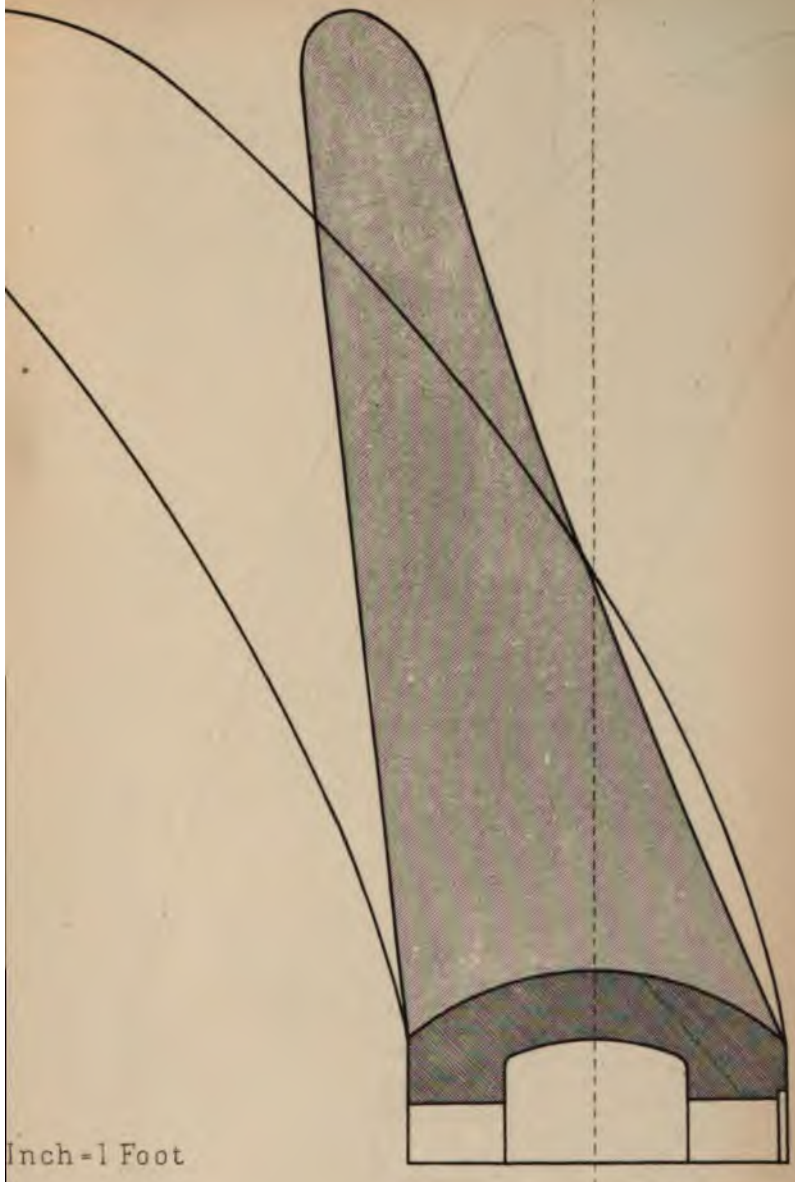


1880 N.E.C. Inst. C.E. & S. 1884 HS



ORDINARY COMPOUND

Diameter 12 Feet.
Pitch 15 Feet 6 Ins.
Surface 36¼ Sq. Feet.



Inch = 1 Foot

THREE CYLINDER ENGINE

Diameter 12 Feet.
Pitch 14 Feet.
Surface 35. Sq. Feet.

the results of Mr. Taylor's engines gave 22·4 and the "Sexta's" engines 21·3 per cent. saving over the two-cylinder two-crank engines. This clearly proved that the results obtained with the "Sexta" corresponded very closely with Mr. Taylor's results; and he thought that would confirm the enormous superiority of the three-cylinder triple expansion engine over the two-cylinder ordinary compound. At all events, it bore out Mr. Taylor's conclusions. He thought there was one thing further that they ought to be indebted to Mr. Taylor for—that was, for so very clearly pointing out the difference between the conditions in the single-cylinder simple expansive engine and the three-cylinder triple expansive one. The great efficiency in the triple expansion engine seemed to him to be gained by dividing the temperature of the steam from that at which it entered the cylinder to that at which it left for the condenser into three distinct parts or stages. There were three small ranges of temperature, instead of one great range, from the boiler temperature right down to that of the condenser.

Mr. JACOB WALLAU said Mr. McFarlane Gray's statement would take a good many of them by surprise, but he supposed they must take it as correct. Another thing which had taken them a little by surprise was that the three-cylinder engine in the S.S. "Sexta" had given such good results. He might, however, say that with the enormous heating surface which it had, that engine had not done as well as it might have been expected. What he thought (and he believed he had mentioned it before) was that Perkins' engine was really dead. He did not think there was a single steamer afloat with a Perkins engine on board. And although Perkins had not been successful, yet he quite agreed with Mr. Taylor that great credit was due to the grandfather of the present Mr. Perkins for making so great a step forward. The Perkins engine had been successful ashore, but of course the conditions ashore were much more favourable for regular working than at sea; although even at sea it might have a better chance of success if they adopted mechanical firing or firing with liquid fuel. He did not see why they should not always have regularity of feed. The saving of size in the Perkins boiler was certainly a point they ought to try to approach as soon as they could. The Perkins boiler had been long before the public: quite true it had not succeeded at sea, but that was not to say that it

might not be improved so as to succeed. Mr. Taylor had thrown out a hint as to what was wanted. It was a question for their young engineers to try their hands at. Considering that in some of the old steamers with Rowan's high pressure compound engines they had obtained an economy equal to anything that had been got since, he was inclined to think it was the increase in pressure that gave them the economy, and not the triple expansion. No doubt what Mr. Taylor said as to the excessive stress got by an early cut-off and high pressure was an objection to the use of one cylinder only. It was a question whether this was not an objection to the two cylinders as well. The difference in the efficiencies between engines using 100 lbs. pressure and 150 lbs. was not quite borne out by theory; but they all knew that theories and facts did not always run closely together. They sometimes differed, but theory and practice were the same thing, and when they were found not to agree, it was simply from a want of accurate observation. For his own part, he would like to see Mr. Taylor's three-cylinder engine tried with the pressure reduced in its boiler to be equal to that of the ordinary two-cylinder compound, and from the data got from such a trial as that it could be more clearly discerned whether the saving was most due to the reduction in the range of temperature, or whether it had been greatly due to simply using higher pressure and greater expansion.

Mr. C. W. HUTCHINSON presumed that the reduced diameter of shaft was an accidental circumstance, owing to the fact of the engine being arranged perhaps to run quicker, since the power of this engine is given off not through three cranks but through two. As a matter of curiosity in detail, he would like to know something about the wrought-iron steam pipes—as to the size which Mr. Taylor had used them, and their thickness. Referring to the Perkins boiler—or tube boiler, if they might so call it—he said a remark had been made that it was almost a perfect boiler if they had really pure water. But where did they get pure water? What was pure water? There was a great difference between the water of the town supply and rain water. Both are drinkable, and both are nominally pure waters; but there exists between them a great difference, which, in the household, is detected in the question of washing, and in the boiler is detected in the question of the existence or non-existence of those substances that would encrust,

corrode, or otherwise damage the boiler. And if the slight differences existing in so-called pure waters just named are so appreciable as we find them to be in the working of boilers, and if they contain the elements of trouble, how much greater the trouble when we come to deal with sea water, and the waters of muddy rivers. Boilers which are sent to sea must be able to meet these difficulties. For instance, he mentioned a case which occurred to him in his sea-going experience. In moving from the moorings at Bordeaux, they had just cast adrift in the river, and were turning round to swing. They were about to start the engines, and he was moving the valve gear, but after the first turn of the engine the valve gear stuck, and the engine could not get away. They tried every device they could imagine, but it was of no use; they could not get it to move. The ship swung round up against the tiers again, and they had to make fast; and, on examination, they found the mud and dirt had been carried through from the surface of the water, and so gummed-up the pistons and valves that they had found it impossible to move them. Therefore, although they might have a boiler which was quite perfect for pure water, in arranging a boiler for sea service it must be equal to such service as he had described. Then the boiler in question, when brought to land service, had a good deal of difficulty under certain circumstances. There was the question of the regularity of firing. There was a great objection to taking mechanical firing to sea, because of the space it occupied and the weight it involved. And with a very small volume both of water and of steam, both the firing and the boiler feed require constant and instant regulation in proportion to the engine speed, and to its stopping and starting, which will sometimes be very frequent.

Mr. JAMES PATTERSON said he quite agreed with what Mr. Wallau had said, that the success of the three-cylinder engines was due, in a great measure, to the use of high-pressure steam. They all knew that economy in the working of steam was got by expansion, and they could not expand steam at 100 lbs. pressure as many times as at 150 lbs., and still have the same terminal pressure. Mr. Taylor, in his paper, had considered the performance of the boats over all, not separating the performance of the engine from that of the boiler, as Mr. Nichol very well pointed out. However, if they looked at Mr. Taylor's figures, they would see that he had reduced the heating sur-

face of the boiler in the three-cylinder engine in the same proportion as he had reduced the coal consumed, therefore, the performances should be exactly equal, and the increase in the efficiency of the performance over all was therefore due to the engines. Mr. Taylor had laid great stress upon the reduction of the range of temperatures in the cylinders. He thought that was a very important point; and in connection with that, he thought a very important point was that in the three-cylinder engines a sufficiently large receiver should be given. If there was a small receiver the pressure must vary, and might cause 20 lbs. variation in the back pressure. That meant 10 lbs. pressure greater range in the cylinders. The question of giving a sufficiently large receiver was not sufficiently attended to sometimes in the designing of engines. Mr. Taylor mentioned, in the end of his paper, that the triple expansion engine at 150 lbs. ought to be cheaper than the other, and he deduced the fact that the boiler would be 5 per cent. lighter in the triple engine than in the ordinary compound. As far as his (Mr. Patterson's) experience had gone, it would be 10 or 15 per cent. heavier.

Mr. R. L. WEIGHTON said, in connection with the question which Mr. Taylor had raised, as to the correctness of the second law of thermo-dynamics, although he had not before seen the startling statement made by Mr. McFarlane Gray, it occurred to him there was an explanation of it, so far, at least, as the question under discussion was concerned. While the theoretical efficiency of different pressures of steam must be expressed by the ratio of temperature range to absolute temperature $\left(\frac{T - t}{T_1}\right)$, as shown on the curve, that only was the case if the two different pressures, or temperatures, of the steam were used under the same conditions in each case. In the one case, in the two-cylinder engine, they had a greater range of temperature in each cylinder than they had in each cylinder of the three-cylinder engine using higher pressures, so that the conditions under which the steam was used were different. Hence the efficiency must be different at the two pressures. So that, so far as the particular instance was concerned, in using steam of different pressures in two different engines, the two-cylinder and three-cylinder, the theoretical curve of efficiency, as expressed in the second law of thermo-dynamics, cannot be expected

to hold. He thought that was quite plain, and the unexpectedly high efficiency of the engines adduced by Mr. Taylor was not at all incompatible with known laws of thermo-dynamics. What Mr. McFarlane Gray might mean when he said "the theoretical efficiency of heat in the cycle steam engine is greater than is expressed by temperature range divided by absolute temperature, and this excess increases as the higher temperature increases," he did not precisely know; but he presumed that the changes in temperature must take place in all cases under identical conditions. Another point is worthy of notice. Investigation of the results of work produced by steam of 100 lbs. and by steam of 150 lbs., as used in the two-cylinder and three-cylinder engines respectively, shows that, roughly, 15 per cent. more efficiency is gained, due to the difference in pressure and difference in ranges of temperature in the cylinders in the two-cylinder as compared with the three-cylinder engine. That percentage agreed very closely with what Mr. Taylor had got. But then came another question. Were they justified (as Mr. Taylor assumed towards the end of his paper) in reducing the heating surface of the boiler to the extent of 15 per cent? Mr. Taylor advocated the reduction from 100 to 85; that was just 15 per cent. At page 115 Mr. Taylor says, "We also have the ordinary kind of heating surface to take up the heat; therefore, the conditions are not changed, so far as the coal and the heat-imparting powers are concerned." True, the coal was the same, and the heating surface was the same; but the conditions under which heat passed through the plates to the water were different, as the water being under a greater pressure was at a higher temperature, and, therefore, the difference of temperature on the two sides of the plate was less. Hence, he thought, that 15 per cent., or the maximum of saving that could be got by using high pressure steam, was too great a proportion in which to reduce the heating surface of the boiler. He thought that Mr. Taylor allowed a rather large reduction in weight, both in the boiler and in the engines. Certainly, the three-cylinder engines would be somewhat heavier. The boilers, in his opinion, would be at least 5 per cent. heavier if constructed with the same factor of safety. There was also an important matter about the shafting which he did not quite understand. It seemed that in the tandem engine—for it was a tandem engine with which Mr. Taylor was dealing—the shaft was

reduced as compared with one of equal power with two cranks and non-tandem. He should have supposed that the tandem engine, having to sustain greater initial loads, would have had the larger shaft.

Mr. J. H. HECK said he had listened with very great interest to the reading of Mr. Taylor's paper. He had recently heard a paper read on triple expansion engines by Mr. A. E. Seaton, before the Institution of Naval Architects, which would confirm Mr. Taylor's assertions so far as economy was concerned. There was one point raised in Mr. Seaton's paper as to triple expansion engines of low pressure, an instance of which was given, and it showed that really the performance of an engine working at 100 to 110 lbs. pressure, with triple expansion, was almost equal to that of a triple expansion engine working at 160 lbs. pressure; and Mr. Seaton distinctly stated that the results which had been got from the three-cylinder engine, working at low pressure, had induced him to reduce the pressure in some cases from 160 to 140 lbs., and that with 140 lbs. they got as good results as they had done with 180 lbs. Reference was made by Mr. Taylor to the second law of thermo-dynamics, and Mr. McFarlane Gray's name had been mentioned in connection with it. He, himself, had had some conversation on the subject with Mr. McFarlane Gray quite recently, and he might say that the difference of temperature referred to was a very well known one, and depended simply on the difference of temperature between the steam in the boiler and the temperature of the condenser, or $\left(\frac{T - t'}{T}\right)$, T being the absolute temperature, and the investigation of Mr. Gray seemed to indicate some variation of the second law. In conclusion, he considered the economy of the triple expansive engines to be due, not so much to increased expansion, but to the better range of temperature obtained in the cylinders.

Mr. W. A. CRAWFORD said most of them must have noticed Mr. McFarlane Gray's report about the second law of thermo-dynamics, but perhaps many of them had not noticed that the Council of the Royal Society had declined to allow him to read his paper before that body. When such men as Professors Sir W. Thompson and Rankine and Clausius found Regnault's experiments sufficient to build up the whole theory of thermo-dynamics, he thought they should be satisfied

with those results. Mr. Taylor had made a remark at the end of his paper regarding the relative cost of the engines. True, the cost per indicated horse-power of the *two-crank* three-cylinder engine might be less than the cost of the ordinary compound engine, but he was quite certain that the reduction in cost indicated did not apply to the three-cylinder *three-crank* engine. A good deal had been said about piston valves. For his own part, he thought there was very little known about the resistance of piston valves. There was another point upon which Mr. Taylor had not touched in his paper—that was the question of the size of the middle cylinder. He was asked repeatedly what size he made the middle cylinder. He thought the simplest way to get the diameter of that cylinder was to make it a geometrical mean between the other two: thus—Let a, b, and c represent the three cylinders in sequence and make $\frac{a}{b} = \frac{b}{c}$

$$\therefore b = \sqrt{ac}$$

or let the first cylinder $= 20''$ and the third $54''$ diameter, then diameter of second cylinder $= \sqrt{(20 \times 54)} \doteqdot 33''$.

Mr. LEWIS said the data which Mr. Taylor had given referred to the whole year's work, and were, in his (Mr. Lewis') opinion, far more instructive and clear than any number of indicator diagrams could have been. And, with regard to indicator diagrams, he would like to point out that the diagrams before them referred to the disposition or working of the steam in the cylinder only, and did not, in his opinion, represent the real horse-power transmitted through the shaft. He considered that if they were to have diagrams representing the actual horse-power exerted by an engine, the diagrams should be modified in accordance with the ratio of length of connecting rod to crank, and they would then have a statement of the exact work passed into the shaft. He was quite sure that in a cylinder where the expansion was very high, or where the cut-off was considerably below 30 per cent., the actual power transmitted into the shaft would be very much less in proportion to the steam used than where the cut-off was later; and he considered it was in this respect the triple-cylinder engines had such an advantage over two-cylinder engines, since they allowed a late cut-off and thereby much better use of the steam in the cylinder. An early cut-off, with 16-fold expansion, would give very little horse-

power at all. Any one could try this for himself by constructing the horse power diagram for the shaft itself, and comparing this with the steam diagram for the cylinder. Triple or quadruple-cylinder engines were more favourably situated than two-cylinder engines, because they allowed a later cut-off, and yet gave a high expansion, and thus gave better results for the steam used.

Mr. J. H. HECK remarked that he would like to say a few words in explanation of the remarks that had been made about Mr. McFarlane Gray's paper. It had been stated that Mr. Gray had sent his paper to the Royal Society, but had not been granted permission to read it. Mr. Gray certainly did send his paper to that body, and a reply was received that fuller information was required of the investigations before the paper could be accepted. Mr. Gray had, however, read two papers on the subject before the Physical Society and the Institution of Naval Architects, and had recently promised that he would publish a volume, giving the whole of his researches into thermodynamics.

Mr. TAYLOR, on rising to reply to the remarks that had been made concerning his paper, said it was a good thing to be told of the "Sexta's" engines, as a great many people—both north and south—seemed to consider that they had invented the triple expansion engine. He thought the greatest stumbling block in the way of the earlier introducers of high pressure and great expansion was that they all went in for some extraordinary boiler; and he took credit to himself for this, that no one had ever put a cargo steamer to sea with a boiler of the ordinary type of construction, and carrying 150 lbs. pressure, until he did it. Mr. Wallau mentioned Perkins' boiler, and thought it might be improved: he (Mr. Taylor) did believe it might be improved; and he knew that the people connected with the Perkins boiler were endeavouring to improve it so as to meet the ordinary requirements, which they found they must provide for if they intended the boiler ever to go to sea again. No doubt it would be a much safer boiler than the ordinary circular multi-tubular boiler; but they must not forget, in designing a new form of boiler, that the ordinary boiler was very hard to beat. Mr. Wallau also thought that the greatest economy was due to the increase of pressure. There was not a shadow of a doubt that as they increased the pressure they must get more out of

the steam if they used it properly. But he did not think that in two-cylinders they could use steam of 150 lbs. pressure as economically as they could in three-cylinders, because they got their cylinder cooled from 406 degrees down to 298 degrees. It was no joke this difference in temperature; the exhaust rushing away at 300 degrees, and the next instant the steam at 400 degrees coming in, must be condensed, and they thus lost power. In the triple-expansion engine the cylinders could be kept at more nearly one temperature, not having a great range of pressure. He was quite satisfied this was the secret of the enormous drop shown on the cards of the Perkins engines. The engine with 150 lbs. pressure had almost the same initial pressure in the cylinder as the Perkins one with 360 lbs. There was really very little difference, and he considered it was simply due to the excessive range. Mr. Hutchinson asked about wrought-iron pipes. He had used wrought-iron pipes up to about 4½ or 5 inches diameter, he did not exactly remember which, and up to the present moment he had not known one of them to fail; and he might say that he had one triple-expansion engine that was built in 1877 or 1878, and up to the present time the boiler had never required one tube to be renewed. True, it was in a yacht, and sometimes was laid up over the winter; but they all knew that a boiler laid up over the winter did not mean that it was saved all the winter. There was another point he mentioned in his paper, namely, that at present there were very vague ideas about the necessary amount of heating surface, and cooling surface, and size of boiler, and size of engines, in proportion to the indicated horse-power. The two boilers named in the paper, the one with the 100 lbs. pressure and the other with the 150 lbs. pressure, were practically the same in efficiency; for this reason, that the one had a low-pressure cylinder of 46 inches diameter and the other of 40 inches. The heating surface was made exactly in proportion to the low-pressure cylinders. The heating surface was arranged to be exactly equal, so that they might take the efficiency of the boilers as the same. That was how one was 1,650 and the other 1,400. He was told that the boilers must be heavier; but they had reduced the heating surface from 1,650 to 1,400, they had reduced the diameter of the boiler from 12 feet 9 inches to 11 feet 8 inches, and reduced the length from 10 feet 6 inches to 10 feet;

and if they calculated the weights of the two boilers (at least this was his calculation) they would find one was five per cent. less weight than the other. They had certainly increased the thickness of the shell in the 150 lbs. pressure boiler, but they had reduced it 13 inches in diameter and 6 inches in length, and all this must tell ; and the very fact that they had reduced the boiler must reduce the space considerably, and yet get sufficient for all practical purposes at sea. The same way with the weight of the engine. He knew they had added another cylinder, and that meant weight; but they had reduced the cooling surface 15 per cent., and that meant that not only the number of condenser tubes was reduced, but they could reduce the shell of the condenser independent of the weight of water they carried. They only required the cooling surface in proportion to their low-pressure cylinder. If they reduced their low-pressure cylinder, everything could be reduced in proportion. As far as the crank-shaft was concerned, it was wondered why he had reduced that crank-shaft. He reduced it according to his ideas at the time he designed these engines; he reduced the shafts in proportion; and he was glad to say this, they had not had one crank-shaft to renew, they had not had one crank-shaft bearing to renew, nor had they had a connecting rod bearing to renew, in the triple-expansion engines. So, at least, it might be said that the diameter of the triple-expansion engine-shaft was sufficient even if he had been rather liberal with the diameter of the ordinary compound one. Mr. Weighton asked what was the meaning of Mr. Gray's statement that the theoretical efficiency of heat in the cycle steam-engine was greater than expressed by temperature range divided by absolute temperature. He thought it was very clear he meant the absolute range divided by the absolute temperature, so as to give the efficiency in the ordinary way. A gentleman asked him why he did not give the consumption per indicated horse-power? As an engineer, he thought that was a most difficult thing to give. On the trial trip they might get 1,000 indicated horse-power; but when the ship went on her voyage she would probably be working at about 600 indicated horse-power regularly. If they took the coal she regularly burned on her voyage, and dealt with 1,000 indicated horse-power, they got a remarkably good statement; but if they dealt with 600 indicated horse-power, they got one which they did not care to tell all their

friends about. There was that difficulty; and he thought the best way to get over it was to take the hours steamed, and the knots steamed, and the coals bought. If they got the hours steamed and the knots steamed, so as to get the mean speed, and the coals bought, they could rely pretty well upon the indicated horse-power being somewhere nearly equal in the two ships. The two steamers were built by Messrs. T. & W. Smith, and might be taken to be practically the same. Each had the same freeboard, and it was the custom of the owners to load them down to that freeboard. In conclusion, he thanked them for the manner in which they had listened to and discussed his paper.

The CHAIRMAN proposed a vote of thanks to Mr. Taylor for his interesting and instructive paper. Mr. Taylor had most successfully introduced the three-cylinder engine. For his own part he thought there would be much further progress in that matter. Whether it be in four-cylinders or in other directions, certainly there would be progress. It would be interesting, he was sure, to all the engineers present to read Mr. Seaton's remarks at the Institution of Naval Architects, as they would appear in the engineering papers. Mr. Taylor had also been very successful in the introduction of high pressures, which was a very important matter indeed. But, as Mr. Taylor had so very clearly brought out, it was not so much a question of high pressures as the careful using of the pressures they had got and the quantity of heat absorbed in the attainment of these pressures; not only the quantity of heat that appeared as registered by the thermometer, but the quantity of heat about which they had yet much to learn; because they must not forget that the temperature that appeared on the thermometer was not a record of the total amount of heat contained in the steam used. There were 1,100 degrees of heat to be dealt with, which, as yet, they had not been able to recover or utilize in the recovery. If that could be done it would be a very great gain to the community at large. He had very great pleasure in proposing a most hearty vote of thanks to Mr. Taylor for his very valuable paper.

The vote was heartily accorded.

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.

FIRST SESSION, 1884–85.

GENERAL MEETING IN THE HALL OF THE SUBSCRIPTION LIBRARY, SUNDERLAND, WEDNESDAY, APRIL 29TH, 1885.

W. BOYD, ESQ., PRESIDENT, IN THE CHAIR.

ON TWISTING MOMENTS ON CRANK SHAFTS OF DIFFERENT ENGINES.

BY RUSSELL SINCLAIR.

THE object of bringing before you the following paper is to compare the variation of the twisting moments, acting on the crank shafts of different types of marine engines, by diagrams of combined twisting moment curves as calculated for each engine.

In the first place, a short description of the method of constructing curves of combined twisting moments may, possibly, not be out of place.

In the case of a single cylinder engine, of which you have the actual indicator diagrams, or theoretical diagrams calculated for the conditions under which the engine is to work, such as shown in Fig. A.

The twisting moment on the shaft for any position of the crank, is found by the formula, $\frac{P \times A \times L \times m}{2240} = M$ (1)

where P = pressure in lbs. per square inch, measured on the diagram at point corresponding to the position of the piston for the respective angle of the crank.

A = area of cylinder in square inches.

L = length of crank in inches.

$m = \frac{\sin(\theta + \phi)}{\cos \phi}$ which gives the leverage due to the obliquity of the connecting rod (*vide* Fig. B).

M = twisting moment in inch tons.

The pressure on the piston (P) for any position of the crank, is the pressure at the corresponding position of the piston, represented by that due to the top of one card and the bottom of the other, as shown in Fig. A, where the full lines show the pressures on the down stroke, and dotted lines those of the up stroke. When compression takes place there being a negative pressure.

The base line of the diagram of twisting moments in Fig. 1 represents the circumference of the crank circle, and on equal divisions, representing say every 20 degrees of angular advance of the crank, ordinates are set up to any convenient scale equal to the twisting moments at the corresponding angle. A curve is then drawn through the several points.

In the case of an engine with two or more cranks and cylinders, to obtain the combined twisting moments, the moments for each crank are calculated separately. The curve for the first crank is drawn as before; the curve for the second crank is then drawn on the same base line, commencing at the point corresponding to the angle its crank makes with the first crank, as in Fig. 2; the curve for the third crank is drawn in like manner, see Fig. 4. The combined twisting moment at each angle is the sum of the twisting moments acting on the several cranks at that angle. Fig. 2 explains the method for a compound engine with two cranks at 90 degrees. Fig. 4 explains the method for a triple expansion engine with three cranks at 120 degrees.

In the foregoing explanation the pressure of the steam on the piston at any point, as measured on the indicator diagram, divided by $\cos \phi$, has been assumed as representing the pressure on the crank pin at the corresponding position of the crank; this, however, is by no means the case, but it will be considerably modified by the inertia of the reciprocating parts, and also in the case of vertical engines by the deadweight of these parts.

Let the angular velocity of the crank pin be assumed as uniform, and the friction be neglected. The reciprocating parts are at rest at the commencement of each stroke, and their velocity increases to, and is at a maximum at mid-stroke, and then gradually decreases to zero at the end of the stroke, when they are for an instant again at rest. The acceleration taking place during the first half of the stroke is produced by a pressure which must be deducted from the pressure of the steam

on the piston, in order to obtain the actual pressure on the crank pin. During the second half of the stroke, the motion of the reciprocating parts is retarded by the action of the crank pin; therefore, the momentum accumulated during the acceleration is imparted as pressure on the crank pin, and must be added to the pressure of the steam on the piston in order to obtain the actual pressure on the crank pin.

Therefore, though the total force acting on the crank pin during the stroke is nearly equal to that acting on the piston, the distribution of the pressures is altered by the acceleration and retardation: *i.e.*, the pressures on the crank pin are less during the first half, and greater during the second half of the stroke, than those on the piston.

From the laws of motion it can be deduced that the force necessary to produce the acceleration of the reciprocating parts of an engine of which the crank is one foot in length, and making one revolution per second, $= \frac{2 \times \cdot0001523 \times 360^2}{32{\cdot}2} \times W = 1{\cdot}227 \times W$ (2)

where W = the total weight in lbs. of the reciprocating parts, ·0001523 = the versed sine of an angle of 1 degree radius unity, and 360 is the number of degrees traversed by the crank during one revolution. Then if

p = the equivalent pressure per square inch on the piston required to produce the acceleration;

A = the area of the cylinder in square inches;

L = the length of the crank in feet;

n = the number of revolutions per second;

$$p = \frac{W \times L \times n^2 \times 1{\cdot}227}{A} \quad (3);$$

or, to put it in a more convenient form, let N = the number of revolutions per minute, then $p = \frac{W \times L \times N^2 \times \cdot00034}{A}$ (4).

As p represents the pressure required to produce the acceleration at the beginning, and retardation at the end of the stroke, the pressure required at any intermediate point of the stroke is found by drawing a diagram as Fig. C. Here A B represents the length of the stroke, or the length of the indicator diagram; ordinates A C, B D, are set off at the beginning and end of A B, equal to p; join C D by a straight line, as for all practical purposes the variation in the velocity

of the piston at opposite ends of the stroke, caused by the obliquity of the connecting rod, may be neglected; then it is seen that the acceleration gradually diminishes to zero at mid-stroke, when the retardation commences and gradually increases till, at the end of the stroke, it is equal to the acceleration. The pressures on this diagram are then measured in the same manner as those on the indicator diagram, at points corresponding to the position of the piston for the respective angles of the crank, and the corresponding indicator pressures decreased or increased respectively.

In vertical engines these pressures are increased on the down stroke and decreased on the up stroke by the addition and subtraction of a pressure $p_1 = \frac{\text{the total weight of the reciprocating parts in lbs.}}{\text{the area of the cylinder in square inches.}}$

Having explained the general method of constructing curves of twisting moments, the consideration of the construction of the particular curves which form the subject of the paper may be proceeded with.

In accordance with the object in view, as mentioned at the beginning, the construction of twisting moment curves of the five following engines form the basis of the paper, and are considered as affording a comparison of, practically, all the different types of vertical marine engines as made. Vertical engines only are dealt with.

No. 1.—Single-cylinder expansive.

„ 2.—Two-cylinder compound, two cranks, angle 90 degrees.

„ 3.—Three-cylinder compound, three cranks, angle 120 degrees.

„ 4.—Three-cylinder triple expansion, three cranks, angle 120 degrees.

„ 5.—Three-cylinder triple expansion, two cranks, angle 90 degrees.

No. 3 is the type of compound engine with one high-pressure cylinder and two low-pressure; No. 5 is the type of triple expansion engine in which the high-pressure cylinder is arranged tandem over the intermediate cylinder, both actuating the same connecting rod and crank.

Diagrams of the twisting moments for these five types are illustrated, showing the curves as calculated in each case, without taking the inertia or deadweight of the moving parts into account; and also

the curves calculated with the alteration due to the deadweight, acceleration, and retardation allowed for. It will be evident that to effect a correct comparison between the different types these calculations must be made under exactly similar conditions for each, as regards :—

(1.) The total indicated horse-power.
(2.) „ length of stroke.
(3.) „ „ connecting rod.
(4.) „ number of revolutions per minute.
(5.) „ terminal and back pressures in low-pressure cylinders.
(6.) „ equal powers in each cylinder of each type.

Now, it would be manifestly next to impossible to obtain five sets of indicator diagrams (one set for each type) from actual practice, which conformed to the foregoing conditions of similarity of terminal and back pressures, equality of powers developed in the several cylinders, and percentage of drop in the receivers, etc. Therefore, it has been considered by the writer that in order to arrive at a correct comparison of the twisting moments, the curves must be constructed from theoretical diagrams calculated for each case in the same manner, which, though it gives conditions that may never be arrived at in actual practice, yet will give a correct *comparison* and also the maximum possible stress; at the same time, to supplement the theoretical examples, curves from actual indicator diagrams are also illustrated.

The theoretical diagrams are all calculated (for the purpose of making them as near to practical conditions as possible) to the $-\frac{10}{9}$ curve, or $PV^{-\frac{10}{9}} = \text{constant}$, and the receiver pressures by the formula $\frac{P}{\left(\frac{R \times r_1}{r_2}\right)^{\frac{10}{9}}}$ where

P = initial absolute pressure ;
R = ratio of cylinders ;
r_1 = ratio of expansion in first cylinder ;
r_2 = ratio of expansion in second cylinder ;

the receiver pressures are assumed as constant during admission, allowance for the effect of wire-drawing, release, and compression being made.

The terminal pressure in the low-pressure cylinders is 10·42 lbs and the back pressure due to imperfect vacuum is 4 lbs.; the ratio of cylinders and ratios of expansion in the cylinders of each example being calculated so as to give equal powers. On reference to Table I. in which the particulars of the theoretical and also the actual diagrams are tabulated, it will be seen at a glance the conditions under which each example is calculated. It will be noticed that the theoretical initial absolute pressure is 45 lbs. in the single-cylinder example; in the compound examples, 100 lbs.; and in the triple expansion examples 165 lbs.; with total expansions of 3·73, 7·65, and 12, respectively, giving the same final terminal pressure of 10·42 lbs.

The particulars of the actual diagrams are also given in Table I. They are not very favourable as a comparison with the theoretical, but are the best the writer could command as regards equal powers in the cylinders of each type, which is a necessary condition for the comparison.

The calculations of the twisting moments from which the curves illustrated are constructed are made from a modification of the formula as given before. As it is not required to reduce the moments to inch tons, as would be necessary were we calculating for any particular size of engine, but a comparison of the effects due to different initial pressures and distribution of the steam being aimed at, therefore, the areas of the cylinders and lengths of stroke and connecting rod are not taken in actual figures, but as unity, *i. e.*, the radius of the crank is assumed as 1, the length of the connecting rod as four times the crank (which is the most usual ratio in marine engines), and the pressures in the cylinders are reduced to terms of an unit of one square inch of high-pressure cylinder. The formulæ for the moments of each cylinder thus become:—

For the high-pressure cylinder ∴ ... $P \times m = M$;

For the intermediate and low-pressure cylinders, $P \times R \times m = M$;

where P = pressure measured on diagram;

R = ratio of cylinder to high-pressure cylinder;

m = multiple as before;

M = twisting moment in pounds per square inch of high-pressure cylinder.

It will be understood from previous formulæ that the acceleration and retardation of the moving parts varies according to angular velocity, and not according to piston speed; therefore, in calculating the curves showing the twisting moments with the acceleration, retardation, and deadweight taken into account, it has been necessary to assume a certain length of stroke and number of revolutions per minute, giving an angular velocity corresponding to an average piston speed, so as to arrive at the pressures for the acceleration diagram.

The conditions assumed are :—Stroke = 42″, revolutions = 70 per minute, which equals a piston speed of 490 feet per minute, the common average.

Now, the weight of the reciprocating parts must be reduced to a ratio of pounds per square inch of cylinder area, so as to form an unit in the same manner as the rest of the calculations; then using the formula given before (4) the pressures required for the acceleration and retardation are found to be $p = 2{\cdot}91 \times w$, where w equals the ratio or unit of the total weight of moving parts in pounds, divided by the area in square inches of the cylinder.

In Table II. are given the weights in pressures per square inch of cylinder or unit, and the pressures required for acceleration, etc., for the several cylinders of each type. These ratios of weights are the means deduced from a number of engines in practice of each different type.

The ratio or weight w is also the pressure due to the deadweight, which is added on the down stroke and substracted on the up stroke.

The alteration to the diagrams which might be caused by the acceleration, etc., of the pumps, is not allowed for, since they may be considered as forming an auxiliary condition applicable to either of the cranks, or to all of them.

In Table III. are given the particulars and ratios of the curves of combined twisting moments for the five different types of engines, as calculated from the theoretical and actual diagrams, both without taking the acceleration, etc., into account, and also with the acceleration, retardation, and deadweight calculated.

In the first three lines of the Table will be found the results in pounds per square inch of high-pressure cylinder, and a glance at them will be sufficient to show that they do not give a comparison such as we aim at, but must be reduced to one scale to do so.

The writer has tabulated them in the hope that they may be found useful to facilitate calculations. Thus, should it be desired to find the twisting moments for any given engine of which the absolute initial pressures and ratios of cylinders and expansions are approximately similar, it is only necessary to multiply the maximum, minimum, or mean, as given in the Table, by the area of the high-pressure cylinder, by the length of the crank in inches, and divide by 2,240 to get the required twisting moment in inch tons.

In the last six lines of the Table these results are reduced to one scale (that of the compound engine, two cranks, being selected), to give the comparison desired, and they correspond with the diagrams illustrated.

It was stated before that one of the conditions under which the curves are calculated was that the total indicated horse power developed be the same in each type; therefore, to reduce them to the scale of the two-cylinder compound engine, the twisting moments, as in the first three lines of Table III., must be multiplied by the ratio which the sum of the mean pressures, reduced to the high-pressure cylinder of each type, bears to that of the compound engine; since, to give equal indicated horse power, the total areas of cylinders will vary in that ratio.

The curves of twisting moments, illustrated in conjunction with Table III., explain themselves, so as to require very little from the writer.

It will be seen that, though in calculating the combined twisting moments for the purpose of arriving at the strength of shafting in a given engine, the effect of the acceleration, etc., of the moving parts may be neglected, since the maximum and mean twisting moments and ratios of maximum to mean are not materially affected. (See Table III.) Yet it is imperative to calculate this effect if we wish to determine the distribution of the twisting moments during a revolution, and the consequent smoothness and efficiency of the engine, because, if the engine moves at all, some pressure is absorbed and given out by the inertia of its moving parts. It is for the purpose of emphasising this point, that the curves and particulars of the non-accelerated pressures have been drawn in each case, as well as the accelerated ones.

The effect of the acceleration and retardation is (as in Fig. 1) to decrease the curve of moments at the beginning of the stroke, and increase it at the end. In the combined twisting moment curves this effect is more important in examples of the two-crank engines than the three-crank engines. In the former it increases the maximum and ratios of the twisting moments considerably (see Table III., and Figs. 2 and 5), where the maximum of 93·2 becomes 96·85, and 92·1 becomes 105·4. In the three-crank types the maximum remains practically the same, and the ratios nearly so. The reason of this difference being, of course, that in the three-crank types, on account of the number of cranks acting at one time on the shaft, and the angles they are set at, the effect of the acceleration, retardation, and deadweight on the three cranks is to counterbalance one another; but in the two-crank types that is not the case, as during one part of the stroke the effect of the individual curves is to increase the combined curve, and during the other part to decrease it. For a clearer explanation refer to Figs. 2 and 4, where the separate curves for each crank are shown. Take any position of the cranks the same for the two examples, say 80 degrees advance of the high-pressure crank on the down stroke. Now, in Fig. 2, the two-crank type the moment of the high-pressure crank at that angle is increased, and the moment of the low-pressure crank is also increased, thus making the combined moment considerably greater than that of ordinary pressures. Again, in Fig. 4, the three-crank type at the same angle of the high-pressure crank, the moments of the high-pressure and intermediate cranks are increased, but the moment of the low-pressure crank is decreased considerably, and thus counterbalances the other two, so as only to slightly increase the combined moment over that of ordinary pressures.

Therefore, the accelerated curves are those upon which the comparisons between the different types are made.

It will be noticed that the mean twisting moments for the different examples are practically the same, with the exception of example No. 1 (the single crank type), which is considerably more in the unaccelerated curves and a little less in the accelerated curves, but it is hardly necessary to compare it with the other types. Of the remaining examples, Nos. and Figs. 2, 3, 4, and 5, the two-crank types, Nos. 2 and 5, are decidedly inferior when compared with the three-crank

types, Nos. 3 and 4, as regards the ratios of maximum to mean, and the equality of the distribution of twisting moments. In No. 2, the curve of combined twisting moments is at the minimum at the commencement of the down stroke, rising during the first 40 degrees of advance to the maximum, then decreasing a little, and, rising slightly, commences before the half revolution to gradually decrease below the mean line, reaching the minimum near the end of the circle. In fact, the curve is almost entirely above the mean line of twisting moments during the down stroke or first half of the revolution, and below it during the up stroke or second half, showing plainly the tendency of the two-crank engine to transmit considerably more power through the shaft during one part of the revolution than the other. This will be corroborated by any one who has seen a two-crank compound engine revolve at slow speed. If the high-pressure crank be watched, it will be seen to move away easily from the beginning of the down stroke, but seems to keep moving with a struggle on the up stroke, even, it may be, threatening to stop altogether as it gets to the top centre, but as soon as it gets over moves away again easily. No. 5 example presents generally the same features as No. 2, but is even a worse case, by reason of the sudden drop from maximum to the minimum at half revolution.

In the three-crank types, Nos. and Figs. 3 and 4, the ratios and distribution of the twisting moments are comparatively even and similar to each other. In neither of these examples have we a sudden rise to the maximum, followed by a curve continually decreasing to the minimum, as in Fig. 2, nor a sudden drop from the maximum, as in Fig. 5; but the variations of the curves above and below the mean line of twisting moments are such that practically as much power will be transmitted during one half of the revolution as during the other, thus conducing to the more even and smooth working of the engine as compared with the two-crank types.

To emphasise this I might add that it was a triple expansion engine of the same type as No. 4 example, of which our esteemed President remarked in his inaugural address, that he had seen "to revolve smoothly and continuously and without stoppage, at 12 revolutions per minute, and I believe this is a result not obtainable in an ordinary compound engine."

In the curves calculated from actual indicator diagrams, and corresponding to Nos. and Figs. 2A, 3A, 4A, and 5A, the twisting moments are, as a matter of course, considerably lower than in the theoretical curves. The mean twisting moments are, as in the theoretical examples, practically alike (see Table III.), and the several ratios and distributions of the moments bear out very fairly the comparisons as made from the theoretical curves. The two-crank types, Nos. 2A and 5A, are not improved on the theoretical, especially No. 5A, in which the ratios are all increased considerably.

With the view of illustrating the effect of the acceleration, etc., due to an increased number of revolutions on the curves of twisting moments of the compound engine, type No. 2, and the triple expansion engine, type No. 4, so as to enable a comparison to be formed between them at high speeds, curves for types Nos. 2 and 4 are illustrated in Figs. 6 and 7, respectively, calculated with an allowance for acceleration and retardation due to 100 revolutions per minute, which equals a piston speed of 700 feet per minute, a rather excessive speed for a vertical mercantile marine engine. The deadweight is the same as before.

In the last two columns of Table III. are given the particulars and ratios of these combined twisting moments, and a comparison of the figures and diagrams 6 and 7 with the former results for Nos. 2 and 4, shows that, while the mean twisting moments are practically not altered, the maximums are increased, and minimums decreased, and the ratios considerably altered, in both examples for the worse, to nearly the same extent; the ratios of $\frac{\text{maximum}}{\text{mean}}$ in No. 2, bearing nearly the same ratio to No. 4 as it does in No. 6 to No. 7. But if the diagrams are compared, it will be seen that the two-crank example has, as before, the combined moments falling below the mean line during the second half of the revolution, while the curve in the three-crank example is still comparatively even in the variations above and below the mean line; so that we may assume that a high number of revolutions may be resorted to,—for the purpose of giving a greater indicated horse power per ton weight of machinery,—with more confidence as regards the twisting moments on the crank shaft in the triple expansion engine with three cranks, than in the compound engine with two cranks.

It might here be mentioned, by way of explanation, that, although a high number of revolutions and consequent increased acceleration pressure has a disadvantageous effect on the combined twisting moments of an engine, yet it has the reverse as regards the shocks on the crank pin caused by the initial pressures in the cylinders, because the greater the acceleration pressure, due to the inertia of the moving parts at the beginning of the stroke, the less will be the pressure exerted on the crank pin. Figs. A and C explain this. Therefore, in a high speed engine, it is an advantage to keep the weights of the reciprocating parts as high as convenient.

As another comparison between the compound and the triple expansion engine, the curves illustrated in Fig. 8 are calculated and represent the twisting moments on the high-pressure crank of examples Nos. 2 and 4, due to the initial steam line in the high-pressure cylinder.

It is assumed that the engines are at rest, and without any pressure or vacuum in any of the cylinders or receivers. The curves represent the twisting moments during the first stroke, due to steam being admitted at the boiler-pressures of 85 lbs. and 150 lbs. respectively; and they show that the maximum initial stress in the compound engine is greater than in the triple expansion engine in the ratio of 1·18.

In conclusion, it may be inferred from the foregoing calculations that, as regards the efficiency of the engine, judged by the twisting moments on the crank shaft, the three-crank types are the superior of the five types examined. Also the triple expansion engine with three cranks, is undoubtedly superior to the compound engine with two cranks, or the triple expansion engine with two cranks. So that we may hope, by adopting the triple expansion system, not only to have a gain in decreased consumption of fuel by increased pressures, but by also adopting the three crank type to have an increased gain in efficiency of the machinery, and also in the life of the crank shafts, as compared with the average of the ordinary two-crank compound engine.

TABLE I.

SHOWING CONDITIONS UNDER WHICH CALCULATIONS ARE MADE.

	THEORETICAL DIAGRAMS.					ACTUAL DIAGRAMS.			
No. of engine	1	2	3	4	5	2A	3A	4A	5A
Initial absolute pressure ...	45	100	100	165	165	95	75	165	165
Total No. of expansions ...	3·73	7·65	7·65	12	12	...	...	...	...
Terminal pressure ...	10·42	10·42	10·42	10·42	10·42	...	...	...	.
Total ratio of cylinders ...	...	4	5·1	6·66	7·06	3·75	3·88	7·78	7·8
Ratio $\frac{\text{Intermediate}}{\text{H.P.}}$ ...	...	...	...	2·57	1·8	...	...	1·34	1·95
Ratio $\frac{\text{L.P.}}{\text{Int. P}}$	...	...	...	2·59	3·92	...	...	2·29	4
No. of expansions, H.P. ...	...	1·9	1·5	1·8	1·7	...	...	...	...
Compression, H.P. in fraction of stroke	$\frac{1}{3·3}$	$\frac{1}{6·25}$	$\frac{1}{9}$	$\frac{1}{9}$	$\frac{1}{11}$	...	...	...	...
Mean pressure, H.P. ...	22·75	61·2	54·2	83·9	59·5	39·4	31	73·1	60·8
1st receiver pressure ...	...	23·9	39·2	59·6	86	...	...	...	...
No. of expansions, I.P. ...	...	...	...	1·85	1·7	...	...	...	...
Rate of compression ...	...	...	...	$\frac{1}{4}$	$\frac{1}{6}$	...	...	...	...
Mean pressure, I.P. ...	...	...	...	32·45	42·75	...	...	22·6	33·1
2nd receiver pressure ...	...	...	...	18·85	32·85	...	...	..	...
No. of expansions, L.P. ...	...	2·1	3·3	1·7	2·8	...	...	...	...
Rate of compression ...	...	$\frac{1}{5·5}$	$\frac{1}{5·5}$	$\frac{1}{5·5}$	$\frac{1}{5·5}$	...	..	...	...
Mean pressure, L.P. ...	...	15·4	21·2	12·6	19·2	10·43	$\frac{15·5}{16·3}$	10·6	11·5
Back pressure of condenser	4	4	4	4	4	...	...	...	...

TABLE II.

PRESSURES DUE TO ACCELERATION, RETARDATION, AND DEADWEIGHT OF RECIPROCATING PARTS.

Stroke = 42″ Revolutions = 70 per minute.

$$w = \frac{W}{A} = \frac{\text{Total weight in lbs.}}{\text{Area of cylinder.}}$$

p = Pressure due to acceleration = 2·91 × w.

No. of engine		1	2	3	4	5
1st cylinder ...	w =	3·5	8·25	6	11·5	22·5
	p =	10·18	24	17·46	33·4	65·47
2nd cylinder ...	w =	...	2·75	2·5	6	...
	p =	...	8	7·27	17·46	...
3rd cylinder ...	w =	...	...	...	2·5	2·5
	p =	...	...	...	7·27	7·27

TABLE III.

Particulars of Combined Twisting Moments.

		No Acceleration Calculated.									Acceleration and Deadweight Calculated as per Table II.									Excessive Acceleration	
		Theoretical Diagrams.					Actual Diagrams.				Theoretical Diagrams.					Actual Diagrams.				Theoretical Diagrams.	
No. of Engine		1.	2.	3.	4.	5.	2A.	3A.	4A.	5A.	1.	2.	3.	4.	5.	2A.	3A.	4A.	5A.	2.	4.
Moments from pressures measured on Diagrams.	Maximum	35·4	93·2	133·1	179·6	204·7	70·2	68·65	195·4	202·15	34·95	96·85	131·8	185·7	234·4	73·55	69·65	182·25	214	100·74	200·1
	Minimum	..	57·35	61·03	112·5	109·5	28·1	44·88	90·93	78	..	52·01	65·65	101·1	113·6	35·86	43·06	103·4	46·8	48·25	94·65
	Mean ..	14·89	75·2	97·6	150·4	165·6	49·1	58·5	146·4	185·54	13·68	74·25	97·75	150·8	166·5	49·94	58·5	146·05	180·25	74·5	149·4
Moments reduced to scale of compound engine No. 2.	Maximum	190·5	93·2	100	87·8	92·1	70·2	58·1	66	73·75	188·1	96·85	99·1	89·5	105·4	73·55	58·95	61·55	78·2	100·74	97·6
	Minimum	..	57·35	45·8	55	49·3	28·1	38	30·71	28·48	..	52·01	49·3	49·4	51·1	35·86	36·4	34·9	17·1	48·25	45·3
	Mean ..	80·1	75·2	73·33	73·51	74·62	49·1	49·54	49·49	50·81	73·66	74·25	73·45	73·68	74·87	49·94	42·52	49·42	49·45	74·5	72·89
	Maximum / Mean	2·37	1·24	1·36	1·19	1·23	1·42	1·17	1·33	1·45	2·55	1·3	1·34	1·21	1·4	1·47	1·19	1·24	1·58	1·35	1·33
	Maximum / Minimum	..	1·62	2·18	1·59	1·86	2·5	1·52	2·14	2·58	..	1·86	2·01	1·81	2·06	2·05	1·61	1·76	4·57	2·08	2·15
	Mean																				

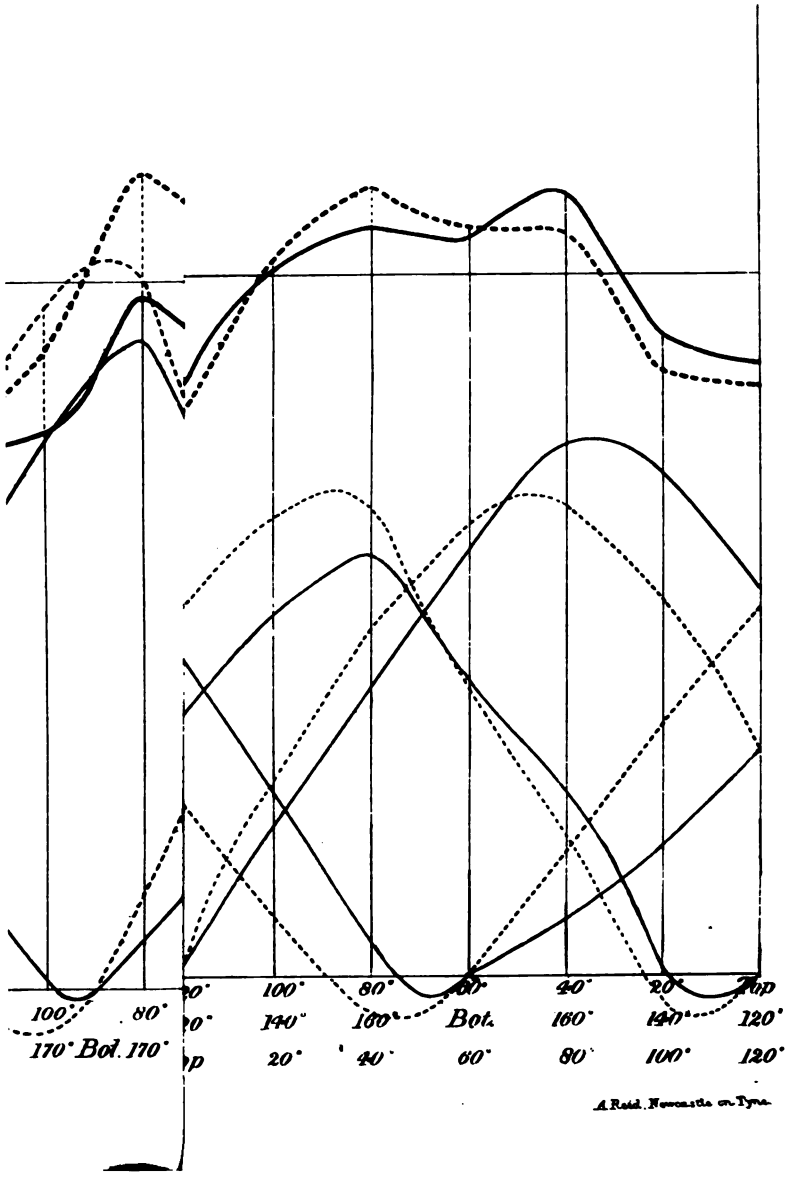


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TABLE III.

Particulars of Combined Twisting Moments.

		No Acceleration Calculated.									Acceleration and Deadweight Calculated as per Table II.									Excessive Acceleration	
		Theoretical Diagrams.					Actual Diagrams.				Theoretical Diagrams.					Actual Diagrams.				Theoretical Diagrams.	
No. of Engine		1.	2.	3.	4.	5.	2A.	3A.	4A.	5A.	1.	2.	3.	4.	5.	2A.	3A.	4A.	5A.	2.	4.
Moments from pressures measured on Diagrams.	Maximum	35·4	93·2	133·1	179·6	204·7	70·2	68·65	195·4	202·15	34·95	96·85	131·8	185·7	234·4	73·55	69·65	182·25	214	100·74	200·1
	Minimum	..	57·35	61·03	112·5	109·5	28·1	44·88	90·93	78	..	52·01	65·65	101·1	113·6	35·86	43·06	103·4	46·8	48·35	94·65
	Mean ..	14·89	75·2	97·6	150·4	165·6	49·1	58·5	146·4	185·54	13·68	74·25	97·75	150·8	166·5	49·94	58·5	146·05	180·25	74·5	149·4
Moments reduced to scale of compound engine No. 2.	Maximum	190·5	93·2	100	87·8	92·1	70·2	58·1	66	73·75	188·1	96·85	99·1	89·5	105·4	73·55	58·95	61·55	78·2	100·74	97·6
	Minimum	..	57·35	45·8	55	49·3	28·1	38	30·71	28·48	..	52·01	49·3	49·4	51·1	35·86	36·4	34·9	17·1	48·25	45·3
	Mean ..	80·1	75·2	73·33	73·51	74·62	49·1	49·54	49·49	50·81	73·66	74·25	73·45	73·68	74·87	49·94	42·52	49·42	49·45	74·5	72·89
	Maximum / Mean	2·37	1·24	1·36	1·19	1·23	1·42	1·17	1·33	1·45	2·55	1·3	1·34	1·21	1·4	1·47	1·19	1·24	1·58	1·35	1·33
	Maximum / Minimum	..	1·62	2·18	1·59	1·86	2·5	1·52	2·14	2·58	..	1·86	2·01	1·81	2·06	2·05	1·61	1·76	4·57	2·08	2·15
	Mean / Minimum	..	1·31	1·6	1·33	1·51	1·74	1·3	1·61	1·78	..	1·42	1·51	1·49	1·46	1·39	1·36	1·41	2·89	1·54	1·61

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90°

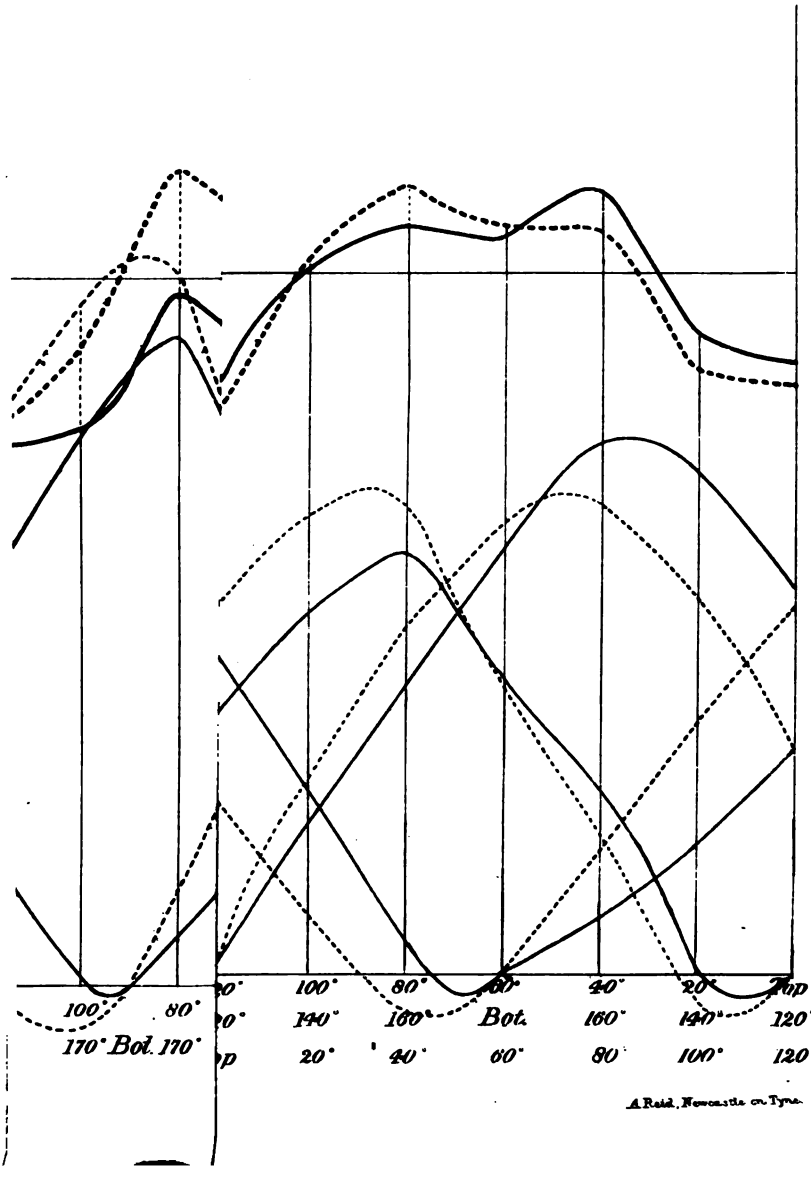

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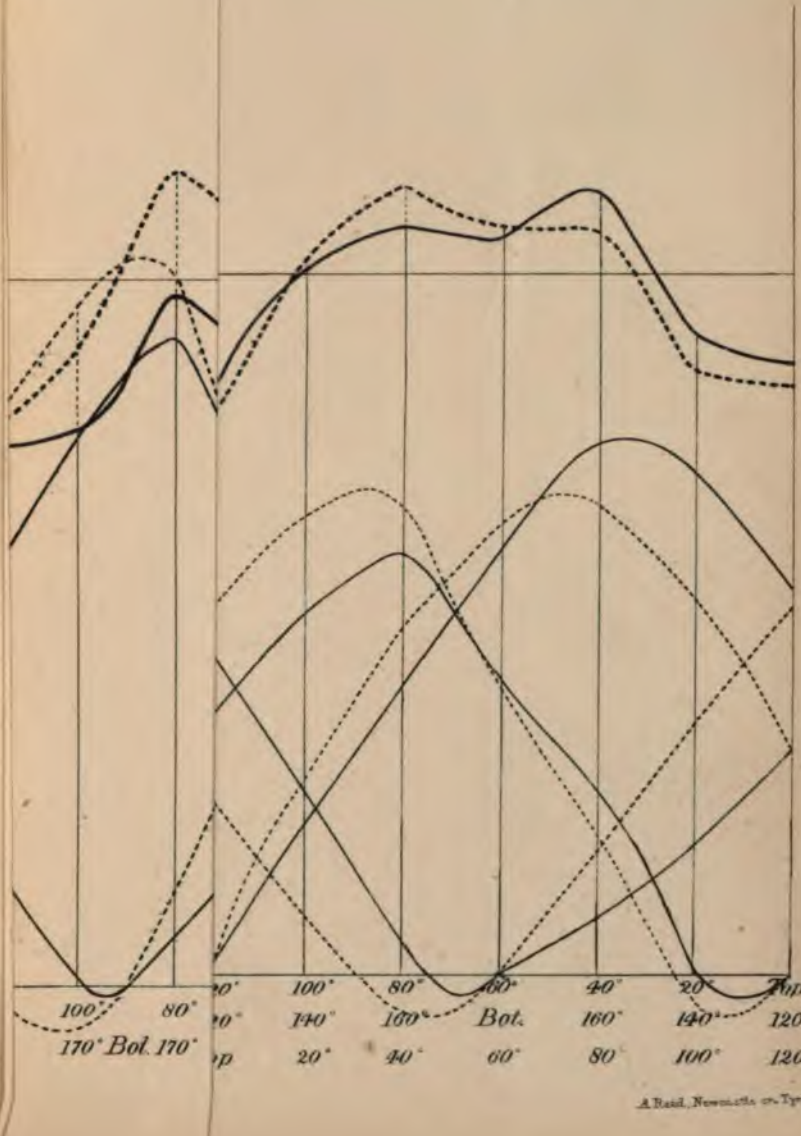
TABLE II.

Particulars of Combined Twisting Moments.

		No Acceleration Calculated.									Acceleration and Deadweight Calculated as per Table II.									Excessive Acceleration	
		Theoretical Diagrams.					Actual Diagrams.				Theoretical Diagrams.					Actual Diagrams.				Theoretical Diagrams.	
No. of Engine		1.	2.	3.	4.	5.	2A.	3A.	4A.	5A.	1.	2.	3.	4.	5.	2A.	3A.	4A.	5A.	2.	4.
Moments from pressures measured on Diagrams.	Maximum	35·4	93·2	133·1	179·6	204·7	70·2	68·65	195·4	202·15	34·95	96·85	131·8	185·7	234·4	73·55	69·65	182·25	214	100·74	200·1
	Minimum	..	57·35	61·03	112·5	109·5	28·1	44·88	90·93	78	..	52·01	65·65	101·1	113·6	35·86	43·06	103·4	46·8	48·25	94·65
	Mean ..	14·89	75·2	97·6	150·4	165·6	49·1	58·5	146·4	185·54	13·68	74·25	97·75	150·8	166·5	49·94	58·5	146·05	180·25	74·5	149·4
Moments reduced to scale of compound engine No. 2.	Maximum	190·5	93·2	100	87·8	92·1	70·2	58·1	66	73·75	188·1	96·85	99·1	89·5	105·4	73·55	58·95	61·55	78·2	100·74	97·6
	Minimum	..	57·35	45·8	55	49·3	28·1	38	30·71	28·48	..	52·01	49·3	49·4	51·1	35·86	36·4	34·9	17·1	48·25	45·3
	Mean ..	80·1	75·2	73·33	73·51	74·62	49·1	49·54	49·49	50·81	73·66	74·25	73·45	73·68	74·87	49·94	49·52	49·42	49·45	74·5	72·89
	Maximum / Mean	2·37	1·24	1·36	1·19	1·23	1·42	1·17	1·33	1·45	2·55	1·3	1·34	1·21	1·4	1·47	1·19	1·24	1·58	1·35	1·33
	Maximum / Minimum	..	1·62	2·18	1·59	1·86	2·5	1·52	2·14	2·58	..	1·86	2·01	1·81	2·06	2·05	1·61	1·76	4·57	2·08	2·15
	Mean / Minimum	..	1·31	1·6	1·33	1·51	1·74	1·3	1·61	1·78	..	1·42	1·51	1·49	1·46	1·39	1·36	1·41	2·89	1·54	1·61

ation.

90°



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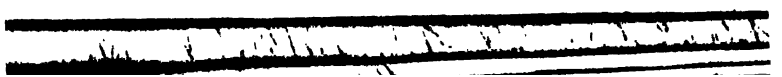


FIG. 3A

OMPOUND ENGINE 3 CRANKS 120°

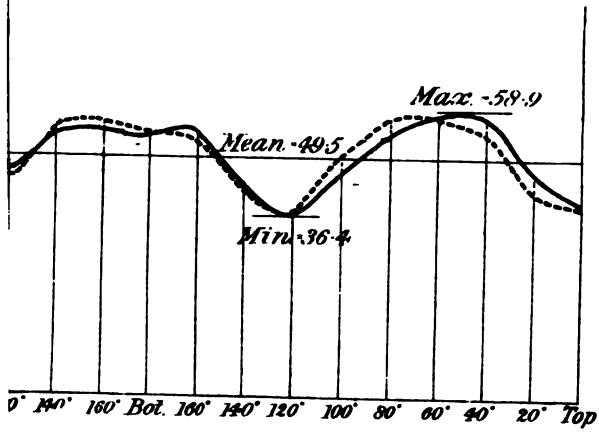
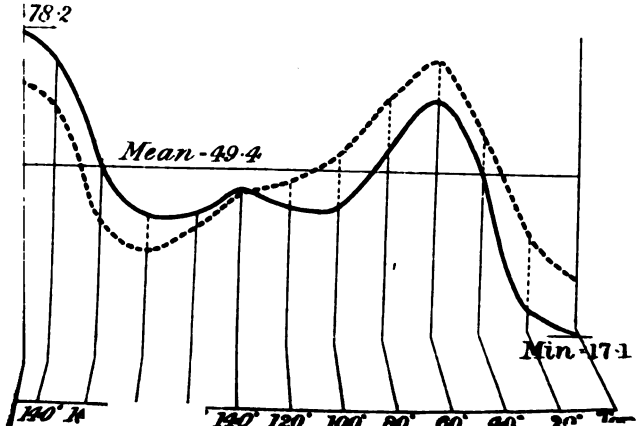
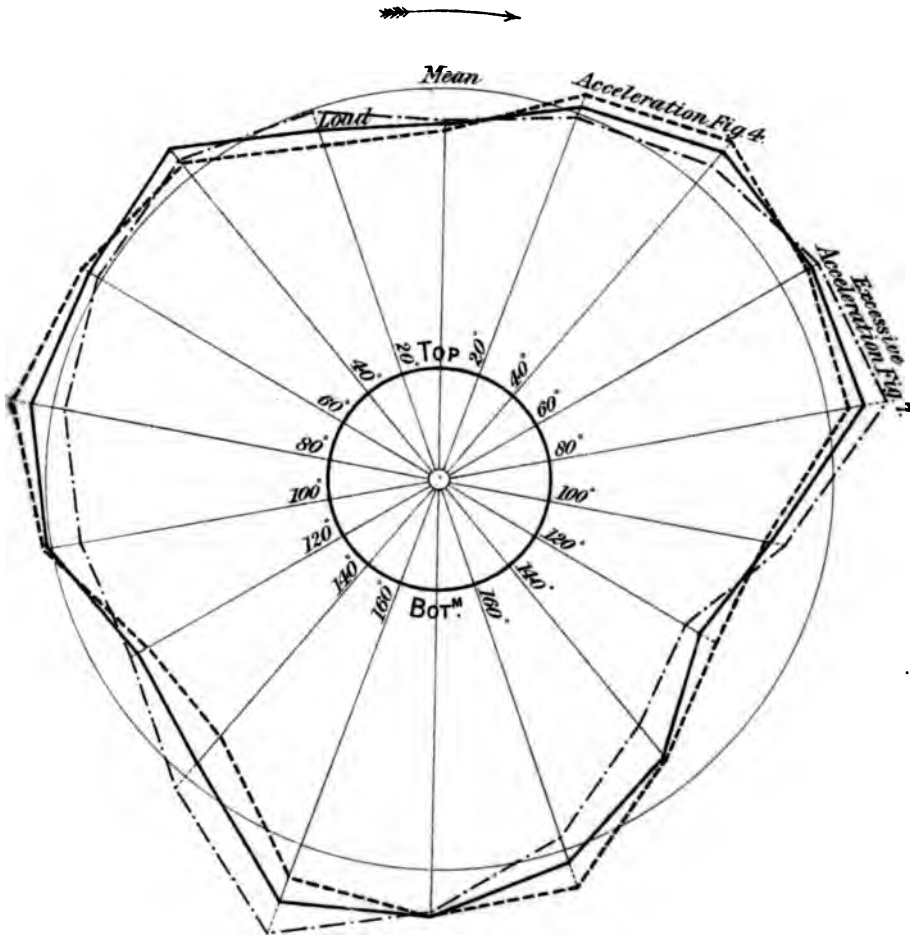
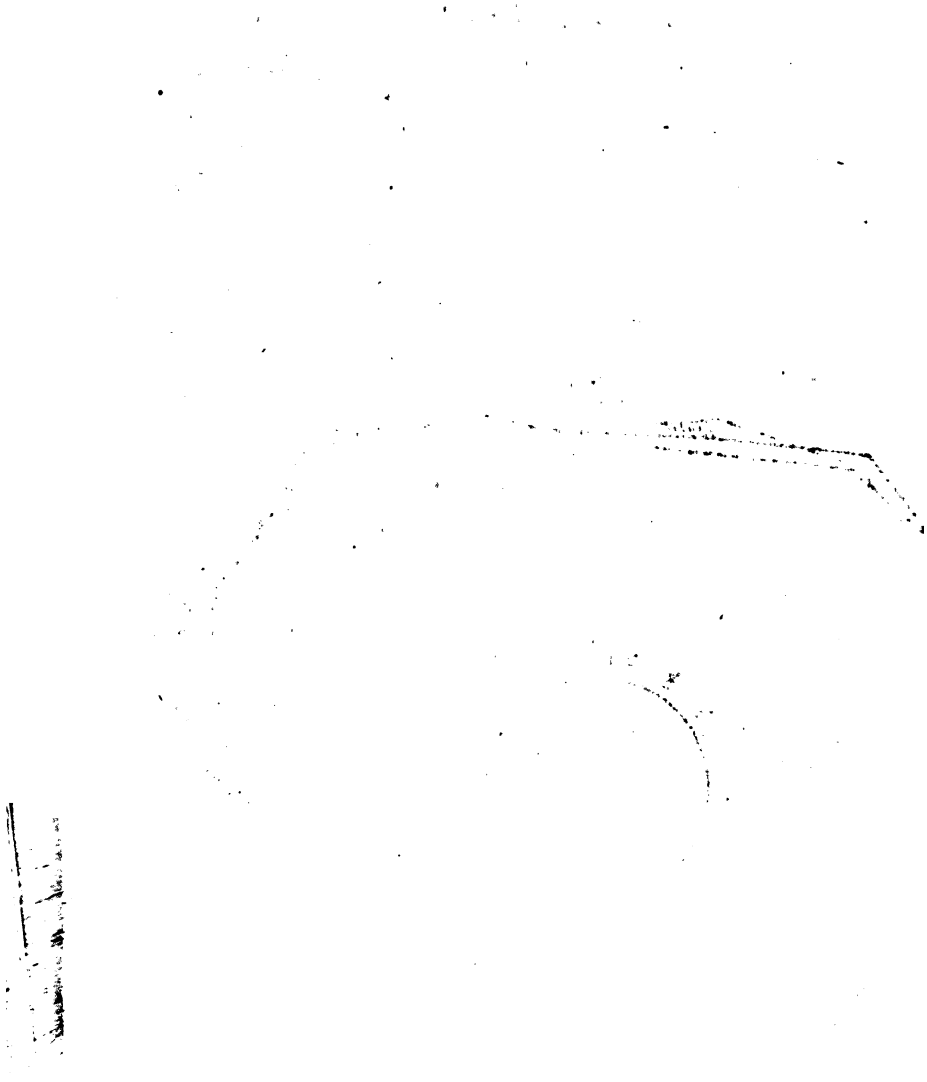


FIG. 5A

ANSION ENGINE 2 CRANKS 90°




Mean
Acceleration Fig 4.
Excessive Acceleration Fig 7.
Load
Top
Bot.m
20°
40°
60°
80°
100°
120°
140°
160°



MR. MAGNUS SANDISON, in opening the discussion, said he was sure that Mr. Sinclair had laid before them the results of a great amount of labour and had shown very clearly the method of laying down a curve of twisting moments. He was pleased to note that the curves showed a negative value at certain points, as in laying down curves of that nature persons inexperienced in the work were apt to make the mistake of measuring the pressures from uncombined indicator diagrams, in which case the curve never falls below the base line, a result which is quite erroneous and misleading, and which Mr. Sinclair in his paper had clearly pointed out. In detailing the conditions necessary for effecting a correct comparison between the different types of engines, Mr. Sinclair, on page 135, specifies equal powers in each cylinder of each type. He (Mr. Sandison) presumed that in the case of the triple expansion tandem engine equal powers on the cranks was obviously what was required, as equality of power in the cylinders of this type would make the stress on the cranks in the ratio of 1 to 2. It was to be regretted they had not got the theoretical diagrams and the actual indicator cards before them, for the purpose of checking the curves for their own satisfaction. In Table No. 1, column 4, for the triple expansion engines, the mean pressure reduced to the low pressure cylinder was between 37 and 38 pounds. This, he thought, was rather high. Of course, practice might vary. Again, the mean pressure, deducting four pounds which Mr. Sinclair allowed for back pressure, gave an efficiency of some 95 per cent., the 5 per cent., or whatever it might be, being loss due to compression, wire drawing, and so on. Mr. Sinclair's diagrams have evidently very square corners. They all knew that a curve of twisting moments, no matter how much it might vary up and down, was still a continuous curve. But looking, for instance, at the accelerated pressure curve for the low pressure cylinder, in Fig. 2, we find that the ends meet in a sharp point or apex, which would never be the case in actual working. As far as they could judge by the eye there ought to be a decided hump, if he might be allowed the expression, between 0° and 20°, so as to make the curves join easily and smoothly into one another. Looking at all the diagrams, he thought they might be modified in the same way, and as they were to be handed down to posterity, he thought this ought to

be done. There was another point, and that was with reference to the mean lines of the curves. For purposes of comparison he thought it would have been more convenient if a uniform value of, say, 100 had been assumed for these mean lines, and the maximum and minimum values calculated accordingly. In this connection, too, in Fig. 1, he did not exactly see why the mean lines did not coincide. He should like Mr. Sinclair to say something on that point, because he imagined that the energy given out during one part of the stroke and absorbed during the other, would be neutralised, and the two means coincide. He was not prepared to give an opinion upon the subject.

Mr. W. A. F. CRAWFORD, in complimenting Mr. Sinclair for his able and comprehensive paper, said there were several details in connection with the paper which he thought open to criticism; and comprehensive as the paper was, he thought it might even have been more so. In treating of the different types of engines, it was assumed, on page 132, that the angular velocity was uniform. He thought that this assumption was not correct, and that the friction should not have been neglected. If the radius vector of the crank pin passed through equal angles in equal intervals of time, then the assumption that the acceleration was positive during the first half, and negative during the second half, was tenable; but from the diagrams actually constructed, the acceleration shown did not justify the hypothesis. To show the variation of acceleration graphically, he had made the horizontal base in Figs. 4 and 7 a circular one, Plate XXII.. The ordinates in Figs. 4 and 7 becoming radius vectors in Plate XXII., it will be seen at a glance where, and of what nature, the acceleration is. The friction in the one, two, and three-cylinder engines was very different. The friction of the glands would be considerably greater for the same capacities of cylinders, as the number of cylinders increased, because the strength of the rods varied as the diameter squared, and the friction varied as the diameter and depth of the packing, and the total depth of the packing would be greater as the cylinders increased in number. For the same capacities the friction on the cylinder walls will vary as the square root of the number of cylinders, thus, if there are 100 fraction units in the one cylinder, there will be $100 \times \sqrt{2} = 141$ units with two cylinders, and $100 \times \sqrt{3} = 173$ units with three cylinders; with four

cylinders the friction would be doubled, and with nine cylinders it would be trebled, and so on. Regarding Mr. Sinclair's statement at the end of the paper, that in high speed engines it was advantageous to keep the weight of the reciprocating parts as high as convenient, this might be true on the hypothesis used, but in practice it was not so, particularly in the case of a horizontal engine in the after part of a steamship, where the inertia of these parts tended to move the ship in the direction of their motion, thus causing the ship to vibrate about its line of motion. It had been stated as remarkable that three-cylinder engines had been observed to run continuously at twelve revolutions per minute. Mr. Potts had seen a two-crank engine on the s.s. "Lutetia" run smoothly and continuously at eight revolutions per minute, the ship being at her moorings; and he (Mr. Crawford) had seen a single-cylinder engine running under ten revolutions per minute regularly.

Mr. JAMES PATTERSON said, as to the advantage of increasing the weight of the reciprocating parts, he had never before heard it contended that this tended to reduce the shocks on the crank pins. If they supposed an engine without any weight in its reciprocating parts, and without any compression, they knew that at the end of the down stroke, and just at the commencement of the up stroke, there was an inrush of steam at high pressure, which caused a blow on the crank pin. In practice they would have compression in that cylinder, and the effect of this compression was that it greatly decreased the shock upon the crank pin. It seemed to him that the effect of the weight of the reciprocating parts was to counteract this compression, and to do away with the good effect it would otherwise have; and if the reciprocating parts were made heavy enough, the inertia would be sufficient to neutralise the pressure altogether. The steam would come in with full effect upon the crank pin and give it a blow. That was the way he looked at the question. Mr. Sinclair comes to the conclusion that the increase of weight is disadvantageous with regard to the twisting moment, but he, Mr. Patterson, remembered that Mr. Porter in his book on *Richard's Indicator* showed that an increase of weight tends to equalise the twisting stress, especially in a single-cylinder engine at high speed. A gentleman had talked about the number of revolutions an engine had been known

to go. He might say that Mr. Johnson, chief engineer of the "Stirling Castle," told him that the engines of that boat had worked steadily down to three revolutions.

Mr. W. CLARK said, he did not rise to criticise the result of the laborious calculations which Mr. Sinclair had made, not having had an opportunity of studying them, but to make an observation on the statement made by Mr. Patterson, viz., that "he thought that if Mr. Sinclair had proceeded by the method given by Porter, in his book on the *Indicator*, he would not have found the accelerating and retarding effect of the inertia so great." Now the manner in which Mr. Sinclair had investigated the effect of the inertia on the reciprocating parts of the engine was the precise manner in which he remembered reading it many years ago in a book by Mr. Porter. He had recognised the formula from which Mr. Sinclair had made his calculations. It proceeded upon the assumption that the acceleration, whilst moving through one degree, was uniform, which was precisely the system adopted by Mr. Porter in his investigations, and which, of course, is not correct. If he could take exception to anything about that paper, notwithstanding its laborious method, it would be owing to the system he had adopted. He thought that Mr. Sinclair might very easily have adopted a much simpler formula, with the advantage of being more correct. He would point out that Mr. Sinclair had, in Fig. A., drawn the line representing the pressures due to the inertia as a straight line. He was not aware that anything in this paper showed that the pressures due to the inertia of the moving parts were represented by this straight line at all. As a matter of fact, by a more rigid examination the equation of the curve *was* shown to be a straight line, but Mr. Sinclair said nothing in his paper to show it; neither did Mr. Porter in his estimate of the work done by the reciprocating of the moving parts. The fact of the obliquity of the connecting rod being neglected would show the curve to be symmetrical with respect to the axes, but he could not see that it could be assumed to be a straight line.

Mr. ALLISON thought that Mr. Sinclair had done his work remarkably well. As for making curves, he must just put them where the pressure went. If Mr. Sinclair had got them correct, they could not be altered to make them exactly ship-shape. But he would con-

sider the real maximum twisting stress on the crank shaft to be at the moment when the engines were suddenly brought up, or running at a high rate of speed, such as experienced when racing at sea in rough weather, or other cause. This might have been brought forward in this paper with advantage.

The PRESIDENT said he thought that members would not mistake the object of this paper. It was not his business nor his duty to reply to Mr. Sinclair's paper, nor to the criticisms which members had offered upon it. Mr. Sinclair was capable of doing that himself. It must not, however, be forgotten that Mr. Sinclair in no part of his paper, directly or indirectly, claimed any novelty for the calculations he had made. He had made use of existing formulæ which were open to everybody, and the only thing that Mr. Sinclair claimed was to have put before the members, in a graphic form, the stresses on crank shafts of different types of engines. This question was receiving a considerable amount of attention at the present moment. Mr. Sandison criticised the mean pressures on the diagrams. All that was good criticism; but as long as the same "*theoretical*" diagram was retained throughout the series, it seemed to him that the object aimed at in the paper had been attained. It seemed to him that the most interesting part of the paper lay in the last page but one, in which Mr. Sinclair assumed it to have been proved that the triple expansion engine, on three cranks, was that particular type which gave evidence of giving the least and the most even twisting moment on the crank pin. He showed the effect of high speed, and argued therefrom that with the triple expansion type of engine a higher speed of piston and a greater number of revolutions could be employed than in the ordinary compound engines. If in these days of competition, by the adoption of this particular type, they could reduce the weight of their engine, and consequently the cost, then economy would be effected in this direction, and a great gain would be the result. The bringing prominently forward of that single fact was worthy of such a paper as they had listened to that night. He did not know that he was competent to discuss the details of the paper, but he should be very glad if any gentleman had any further remarks to make.

Mr. SINCLAIR, in replying to the discussion, said, in reference to Mr. Sandison's remarks as to the desirability of laying the theoretical

and indicator diagrams before the members, perhaps it might have been better to have done so, but he did not see they were absolutely necessary, as he had tabulated sufficient data to enable any member to lay down at least theoretical diagrams for themselves. The mean pressures, as Mr. Sandison pointed out, were undoubtedly high, but, as stated in the paper, the figures were constructed for *comparative purposes only*. The mean values were also high, but they give the maximum possible stress. He must admit that the curves did not come in very well at the ends, but had they been calculated for every separate degree he thought they would find that the curves came out more irregular than those illustrated. What he was afraid he would have been brought to task for, was for having showed them too fair. Mr. Sandison was slightly wrong when he said the mean lines in Fig. 1 should coincide.

Mr. SANDISON here remarked that on this point he merely asked for information.

Mr. SINCLAIR continuing, said that when acceleration, retardation, and dead weight were all considered the mean lines would not coincide, if they did not take the dead weight into account they would do so, the weight added on the down stroke and deducted on the up stroke, caused the difference. The variation in the velocity was not uniform, he knew, but to go into it carefully would have required a great amount of labour, which, seeing that he was working for comparison, he did not think was necessary; were he calculating the twisting moments for one particular engine only, he would take the variations in velocity into consideration. The initial pressure of the steam could not cause a shock on the crank pin if the weight of the reciprocating parts were so heavy, that the force due to the steam would be absorbed by the inertia of these parts before acting on the pin, viz., if in Fig. C, AC is equal to the initial pressure. Of course, were there any play on the brasses a shock would occur.

Mr. CLARK here remarked that if Mr. Sinclair had proceeded upon the principle given in Mr. Porter's book, he would have found that this was not the case, or not the case to the same extent. What was in the paper was precisely Mr. Porter's system, adopted by Mr. Sinclair. It might have belonged to someone else before Mr. Porter, but as he had mentioned, it had been written by Mr. Porter upwards of sixteen years ago.

Mr. SINCLAIR then went on to say, that as regarded acceleration at high speeds, he had shown it at ordinary and excessive speeds, and when racing he would expect it to appear higher than in Fig. 6. The friction taken up by the motion bars was very small, in fact, the maximum amounted to less than three per cent. When he commenced the paper, it was for the purpose of forming a comparison, but had, as he went on, tabulated his results, in the hope that they might be useful for reference.

The PRESIDENT said they might congratulate themselves upon the series of papers they had had during that, their first session. He would beg them now to pass a vote of thanks to Mr. Sinclair for his paper.

The vote was carried by acclamation.

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.

First Session, 1884-85.

MINUTES OF PROCEEDINGS.

The Opening General Business Meeting of the Institution was held in the Hall of the Literary and Philosophical Society, Newcastle-on-Tyne, on Thursday, November 20th, 1884, at 7.30 p.m.

Mr. C. W. Hutchinson, the Chairman of the Provisional Committee, in the chair.

The Chairman declared to the meeting that, as the result of the ballot among the Members, the following had been elected Officers of the Institution :—

President.

W. Boyd.

Vice-Presidents.

W. J. Clark.	W. Richardson.
C. W. Hutchinson.	R. Thompson.
F. C. Marshall.	W. H. White.

Honorary Secretary.

W. G. Spence.

Honorary Treasurer.

B. G. Nichol.

Councilmen.

W. A. F. Crawford.	I. Mavor.
J. Darney.	A. R. Mackintosh.
R. Doxford.	J. Price.
G. B. Hunter.	R. Sinclair.
J. H. Irwin.	H. F. Swan.
J. Laing, Jun.	A. Taylor.
H. Macoll.	P. D. Winstanley.

J. Weir.

Mr. F. C. MARSHALL moved a vote of approval of the mode of election.

Seconded by Mr. H. CHARLTON.

Carried unanimously.

The CHAIRMAN then formally handed over the Institution to the President.

Mr. F. C. MARSHALL proposed a vote of thanks for their services in founding the Institution, to those members of the Provisional Committee who had not been elected on the Council of the Institution, viz., W. G. Green, F. T. Hansen, T. Millar, W. J. Milne, W. Stephenson, J. C. Stirzaker, and T. R. Williams.

Carried with acclamation.

The PRESIDENT invited discussion on the following draft of the proposed Constitution as submitted by the Provisional Committee.

"MEMORANDUM OF PROPOSED CONSTITUTION OF THE NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.

THE OBJECTS for which this Institution is being formed are :— To hold meetings for the Reading and Discussion of Papers connected with the Science of Engineering and Shipbuilding ; to facilitate the exchange of ideas and information amongst its members, and to place on record its transactions.

The Institution shall consist of Members, Associates, Graduates, and Honorary Members.

MEMBERS shall be Principals, or Principal Managers engaged in Engineering or Shipbuilding, Civil, Military, or Mining Engineers or Naval Architects, whose Subscriptions shall be Two Guineas per Annum ; and other persons engaged in the above professions, whose Subscription shall be Half-a-Guinea per Annum.

ASSOCIATES shall be such persons as are not strictly Engineers or Shipbuilders, but are connected with or interested in such pursuits, and are deemed by the Council to be eligible for Associate Membership. Subscription, One Guinea per Annum.

GRADUATES shall be persons under twenty-one years of age, engaged in study or employment to qualify themselves for any of the above professions. Subscription, Five Shillings per Annum.

HONORARY MEMBERS shall be such distinguished persons, engaged in the above professions, as the Council may elect.

Any Member may become a LIFE MEMBER by a single payment of Twenty Guineas, or any Associate may become a LIFE ASSOCIATE by a single payment of Ten Guineas.

The COUNCIL shall consist of a President, six Vice-Presidents, fifteen Members of Council, a Secretary, and a Treasurer.

The President, Secretary, and Treasurer shall be elected annually. Two Vice-Presidents and five Members of Council shall also be elected annually.

The retiring Vice-Presidents and Members of Council shall, at the end of the first year, be decided by ballot from the whole number; at the end of the second year, by ballot from the number who have served two years; and each succeeding year they shall be those who have served three years from their last election. No retiring Officer or Member of Council shall be eligible for re-election until one year after his retirement, with the exception of the President, who shall be eligible for re-election for a second year, but, after two years' service, not again until after an interval of one year.

Associates shall have all the privileges of Members, with the exception of voting and holding office.

The MEETINGS shall be held monthly, from about October to April each session, in Newcastle and Sunderland, as the Council may arrange."

The name of the Institution as "The North-East Coast Institution of Engineers and Shipbuilders," was adopted.

Mr. F. C. MARSHALL moved that the objects of the Institution be stated thus:—"The objects of this Institution are the advancement of the science and practice of engineering and shipbuilding, and the interchange of ideas and information amongst its members, by means of meetings for the reading and discussion of papers relating thereto, and placing on record its transactions."

It was decided to leave the exact wording to the Council.

Mr. J. PATTERSON moved, as an amendment to the clause relating to the annual subscriptions:—"That the subscriptions be 10s. 6d. all round."

Seconded by Mr. D. MYLES.

The amendment found no further support.

Mr. J. ROWE suggested that there be a third or intermediate subscription—say of one guinea.

Mr. H. F. SWAN moved "That the subscription of Associates joining after this date be two guineas per annum."

Seconded by Mr. F. C. MARSHALL.

After some discussion the motion was withdrawn.

Mr. ALEX. TAYLOR suggested that Associates should have the power of voting.

It was eventually agreed to leave the matter for the consideration of the Council.

Mr. J. DARNEY inquired if Draughtsmen employed in shipyards would be required to subscribe as Naval Architects?

Mr. C. W. HUTCHINSON explained that only Consulting Naval Architects was implied in the clause.

After an inquiry from Mr. J. MACPHERSON GRANT,

Mr. F. C. MARSHALL moved "That Honorary Members, Associates, and Graduates shall have all the privileges of members, with the exception of holding office and voting."

Carried unanimously.

Mr. C. W. HUTCHINSON moved "That each member be entitled to bring a friend to the Inaugural Meeting and to each of the Monthly Meetings during the present Session."

Seconded by Mr. H. F. SWAN.

Carried unanimously.

The meeting closed with complimentary votes of thanks, and a vote of thanks to the Committee of the Literary and Philosophical Society, for the use of the Lecture Hall.

The Inaugural Meeting of the First Session of the Institution was held in the Lecture Hall of the Literary and Philosophical Society, Newcastle-on-Tyne, on Thursday, 28th November, 1884, at 7·30 p.m.

W. BOYD, Esq., President, in the chair.

The HON. SECRETARY read the Minutes of the General Business Meeting, on November 20th, 1884.

The PRESIDENT then read the In

Mr. C. W. HUTCHINSON proposed a vote of thanks to the President for his address.

Seconded by Mr. ROBERT THOMSON.

Carried unanimously.

Mr. WM. CLARK, Mr. WHITE, Mr. STIRZAKER and Mr. MARSHALL addressed the meeting.

The First General Meeting of the Institution was held in the Lecture Hall of the Literary and Philosophical Society, Newcastle-on-Tyne, on December 22nd, 1884, at 7·30 p.m.

W. BOYD, Esq., President, in the chair.

The PRESIDENT read a letter from Sir W. G. Armstrong intimating his acceptance of the first Honorary Membership of the Institution.

Mr. W. H. WHITE then read a paper on "The Speed Trials of Steamships."

A discussion followed the reading of the paper.

The PRESIDENT proposed a vote of thanks to Mr. White for his paper.

The motion was carried by acclamation.

The Second General Meeting of the Institution was held in the Lecture Hall of the Subscription Library, Fawcett Street, Sunderland, on Monday, January 26th, 1885, at 7·30 p.m.

W. BOYD, Esq., President, in the chair.

The Minutes of the General Meeting of December 22nd, 1884, having been read by the Secretary, were approved of by the meeting, and signed by the President.

Mr. HENRY FOWNES read a paper entitled "A Few Practical Remarks on the Forging of Crank Shafts in Iron and Steel."

A discussion followed the reading of the paper.

A vote of thanks to Mr. Fownes for his paper was proposed by Mr. H. MACOLL, and carried by acclamation.

The Third General Meeting of the Institution was held i
Lecture Hall of the Literary and Philosophical Society, Newcast
Tyne, on Wednesday, February 18th, 1885, at 7·30 p.m.

W. BOYD, Esq., President, in the chair.

The Minutes of the General Meeting on Monday, January
were read by the Secretary, approved of by the meeting, and sign
the President.

A paper by Mr. A. E. LONG, on "Approximate Curves of Sta
for Ships," was read by the Secretary.

A discussion followed the reading of the paper.

A vote of thanks to Mr. Long for his paper was proposed b
PRESIDENT, and carried by acclamation.

An Extraordinary General Meeting of the Institution, to
sider the draft of the Constitution and Bye-Laws, as submitte
the Council to the members of the Institution, was held in the Le
Hall of the Literary and Philosophical Society, Newcastle-on-T
on Wednesday, March 4th, 1885, at 7·30 p.m.

W. BOYD, Esq., President, in the chair.

The PRESIDENT, in opening the meeting, said, as at the forma
of the Institution in last autumn, the members were very gre
indebted to Mr. Hutchinson for his services, and the labour he un
took in drawing up the draft of the Constitution, so now, later
the members, and especially the Bye-Laws Committee, were
greatly indebted to Mr. Hutchinson for the labour he had besto
on the draft of the Constitution and Bye-Laws now laid before th
He was sorry to say that Mr. Hutchinson would not be able to
present at the commencement of the meeting, but he believed
would be there later on; but, whether absent or present, he thou
it was only right that record should be made of his services to
Institution in this respect. He also said that the Constitution
Bye-Laws were laid before the members that evening as recommen
tions of the Council, but that it was quite in the power of
member present to propose, in any one of them, any alteratio

modification that he might think fit. He would commence with page 1, and go through the Articles of the Constitution seriatim, and if any member had any modifications to propose, he hoped he would be good enough to speak.

Mr. F. C. MARSHALL said that before going on to consider the Constitution, he would suggest that the explanatory note on page 1 be transferred to come in at the end of the section of Constitution.

This was agreed to.

Articles I., II., III., and IV. were adopted.

Mr. M. SANDISON proposed as an amendment that Article V. should read as follows:—"Members shall be Principals, or Principal Managers, engaged in Mechanical Engineering or Shipbuilding, Civil, Military, or Mining Engineering, or Naval Architecture, whose subscriptions shall be two guineas per annum; and other persons engaged in the above professions whose subscriptions shall be half-a-guinea per annum."

Seconded by Mr. P. MÖRK.

On the amendment being put to the meeting it was lost, and the article was adopted as submitted in the draft.

Articles VI., VII., VIII., and IX. were adopted.

Mr. MARSHALL proposed as an amendment to Article X:—"That the clause requiring Vice-Presidents and Councilmen to retire at the end of three years be eliminated."

Seconded by Mr. SWINBURNE.

The PRESIDENT pointed out, by way of explanation, that the clause was introduced to insure the introduction of fresh blood; and also pointed out that the rule did not say they were not eligible for re-election at all, but merely that they were not eligible for re-election until after an interval of one year.

Mr. STIRZAKER remarked that if Mr. Marshall altered his amendment so as to make it compulsory for only Councilmen to retire, he would have a better chance of getting it carried.

Mr. W. H. WHITE supported the article as submitted in the draft.

After some discussion, Mr. Marshall agreed to withdraw his amendment, and the clause was confirmed.

Articles XI., XII., XIII., XIV., XV. were adopted.

The consideration of the Bye-Laws was then proceeded with.

Mr. STIRZAKER proposed that clause 1 read—"The form shall be signed by a Member or Associate of the Institution as proposer, and by at least other three Members or Associates as supporters," etc.

Agreed to.

Clause 2.—Mr. STIRZAKER pointed out that this clause said, "Associates or Graduates desirous of becoming Members, shall be proposed and recommended according to Form B in the Appendix. The proposal so made shall be submitted to the Council, who shall agree to or reject it." He wished to know if the recommendation would be afterwards submitted to a General Meeting of Members; he thought the wording left the matter rather in doubt.

The PRESIDENT said that the clause was intended to say that the question of *transference* in membership would be a question for the decision of the Council solely.

Mr. W. H. WHITE suggested that, to make the matter clearer, the words, "on behalf of the Institution," be added to the clause.

After some discussion, it was suggested that the question of transference from Graduateship to full Membership should rest solely with the Council. In the case of an Associate wishing to become a Member, application for admission as such to the Institution would have to be made in the manner adopted for applicants for membership of persons who were not members of the Institution, as in Form A in Appendix.

To meet this view, Mr WHITE moved "That the word 'Associate' be struck out of clause 2."

Seconded by Mr. MARSHALL.

Carried unanimously.

Clauses 3 to 10 inclusive were adopted.

Clauses 11 and 12.—Mr. R. L. WEIGHTON moved as an amendment, that clause 11 read thus:—"A voting list shall be prepared under the direction of the Council, in accordance with Form M in Appendix. The list shall show who remain in office throughout the Council, and who are retiring. A copy of the list shall be forwarded to each Member and Associate (at least seven clear days before the May General Meeting), together with a complete list of Members to be filled in, in accordance with the instructions printed on the ballot

form, and may be returned by post to the Secretary, or may be deposited in the ballot box by the voter in person, at the May meeting for the transaction of general business." Also that clause 12 read:—"A scrutiny of voting papers shall be carried out at the May meeting by two persons nominated by the Chairman, and the result shall be declared by the Chairman. The newly-elected officers, after being declared, shall enter into office forthwith; and this shall be the last meeting of the session."

The PRESIDENT said that part of what Mr. Weighton had proposed had already been under discussion at the Council meeting, held just before the general meeting, and had in a sense been accepted; and the Council recommended that after the word Appendix the clause should read: "Such lists shall be presented at the general meeting immediately preceding the last general meeting of the session, and any member present shall be at liberty to nominate additional names, a copy of the list to," &c., the rest to be as in the printed draft.

Mr. WEIGHTON asked if it was intended to have the nomination and election in one meeting?

The PRESIDENT explained that the meaning intended to be conveyed was, that the Council would submit their nominations to a general meeting, and that at that meeting any member present could nominate additional names. The voting lists, containing the whole of these names, would then be sent to each member, thus giving equal publicity to the nominations of members as well as the nominations of the Council. These lists would then be returned to the Secretary, to be opened in the presence of the Council, and counted and scrutinized by them.

Mr. R. L. WEIGHTON said he still questioned the propriety of giving the Council a separate power of nominating. He thought the whole responsibility of the transaction should be thrust on the whole body of the Institution.

Mr. STIRZAKER supported the clause as recommended to be altered by the Council.

Mr. WEIGHTON agreed to withdraw the first part of his amendment, but desired to hold to the second part requiring the votes to be counted at the general meeting by two scrutineers appointed by the Chairman.

Mr. F. C. MARSHALL supported the votes being counted by the Council.

Mr. W. H. WHITE drew attention to the sentence in the clause saying, "and the number of nominations shall be two in excess of the number required in each section of the Council." He wished to know if it was meant that no more than two in excess of the number required could be nominated? He begged to move that it be altered to read, "and the number of nominations shall be at least two in excess of the number required in each section of the Council;" also, that the clause end with the following words: "Any member, in voting, shall be at liberty to add or erase the names of any other members for election, besides those already placed on the ballot list by the Council and members of the Institution," a note indicating this to be printed on the Ballot Form M in the Appendix.

Seconded by Mr. I. MAVOR, and carried unanimously.

The second part of Mr. Weighton's amendment did not find a seconder, and consequently fell through.

Clauses 13, 14, 15, 16, 17, and 18 inclusive, were adopted.

Clause 19.—Mr. STIRZAKER pointed out that the words, "when five members or associates, or both," admitted of a wrong construction, and might mean five members or five associates, or ten persons, he recommended that the wording be, "when five persons being members or associates."

It was finally agreed that the words, "or both," be expunged.

Clauses 20 to 26 inclusive were adopted.

Clause 27.—Mr. STIRZAKER inquired if the term "outside" meant outside the Institution? If so, he thought it would be preferable to get the outsiders inside the Institution first.

Mr. F. C. MARSHALL supported the clause, giving the Council power to appoint persons outside the Institution on special committees.

Mr. STIRZAKER did not press the amendment, and the clause was adopted.

Clauses 28 to 34 inclusive were adopted.

Clause 35.—Mr. W. H. WHITE moved as an amendment "that the words" must be written in the third person, and be omitted.

Seconded by Mr. R. L. WEIGHTON.

Carried.

Clauses 36 to 45 inclusive were adopted.

Clause 46.—Mr. W. H. WHITE asked if, by clause 46, the discussion on a paper could be re-opened without consultation with the author of the paper? also, re-opening the discussion of a former paper might come to sometimes postponing the reading of a paper set down for a particular evening?

The PRESIDENT said the Council would only sanction the re-opening of a discussion provided they saw their way to make some arrangement.

Mr. WHITE said it seemed to him the paragraph might cause trouble. A member wishing to re-open a discussion might read a paper on the subject.

The PRESIDENT said he might not get the paper accepted.

Mr. F. C. MARSHALL thought the case was met by the clause saying, "provided the Council decide to include it in the notice of that meeting as part of the business to be transacted."

Mr. WHITE proposed that clause 46 be omitted from the Bye-Laws altogether.

Seconded by Mr. F. C. MARSHALL,

Carried unanimously.

Clauses 47 and 48 were numbered 46 and 47, and adopted.

Forms A, B, C, D, E, F, G, H, EE, FF, J, K, and L, in Appendix, were adopted.

In regard to Form M, the PRESIDENT pointed out that the word "not," in reference to the re-election of treasurer, was a clerical error, and ought not to exist in the draft; also, in view of the addition which had been made by Mr. White to Bye-Law 11, it would be necessary to add a foot-note (*f*). He thought they could not do better than adopt the words in the rules of the Mining Engineers, viz., "A copy of this list shall be posted, at least seven days previous to the annual meeting, to every member and associate, who may erase any name or names from the list and substitute the name or names of any other person or persons eligible for each respective office; but the number of persons on the list, after such erasure or substitution, must not exceed the number to be elected to the respective offices."

The above modification to Form M was agreed to.

The PRESIDENT then moved, "That the Constitution and Bye-Laws as now modified by the members be accepted as the Constitution and Bye-Laws of the Institution."

Carried unanimously.

The Fourth General Meeting of the Institution was held in the New Assembly Hall, Sunderland, on Wednesday, March 18th, 1885, at 7·30 p.m.

W. BOYD, Esq., President, in the chair.

The Minutes of the General Meetings on February 18th and March 4th, 1885, having been read by the SECRETARY, were approved by the meeting and signed by the President.

Mr. JOHN A. ROWE read a paper on "Boiler Construction and Preservation."

A discussion followed the reading of the paper.

A vote of thanks to Mr. Rowe for his paper was proposed by the PRESIDENT and carried by acclamation.

The Fifth General Meeting of the Institution was held in the Lecture Hall of the Literary and Philosophical Society, Newcastle-on-Tyne, on Wednesday, April 1st, 1885, at 7·45 p.m.

F. C. MARSHALL, Esq., Vice-President, in the chair.

The Minutes of the General Meeting of March 18th, having been read by the SECRETARY, were approved by the members and signed by the Chairman.

A paper on "Triple Expansion Engines" was read by Mr. ALEXANDER TAYLOR.

A discussion followed the reading of the paper.

A vote of thanks to Mr. Taylor for his paper was proposed by the CHAIRMAN and carried by acclamation.

The Sixth General Meeting of the Institution was held in the Lecture Hall of the Subscription Library, Fawcett Street, Sunderland, on Wednesday, April 29th, 1885, at 7·30 p.m.

W. BOYD, Esq., President, in the chair.

The ASSISTANT-SECRETARY having read the Minutes of the General Meeting on April 1st, 1885, they were approved by the meeting and signed by the Chairman.

Messrs. Laing and Mavor were appointed scrutineers to examine the ballot of the applications for membership approved by Council at their meeting of Monday, April 20th. The result was that the following were declared elected:—As members—Messrs. C. W. Taylor, Oscar Gad, Frank Callis, T. D. Widdas, T. W. Smith, Henry Foster, and J. W. Donovan; as graduates—Wm. Reavell, J. T. Wilson, and J. M. F. Tone.

The PRESIDENT having read the list of retiring officers, and also the list of nominations for the vacancies as proposed by the Council, called upon the members to add any further nominations they might consider necessary.

LIST OF OFFICERS RETIRING IN VIRTUE OF CONSTITUTION.

President—W. BOYD.

Vice-Presidents—WIGHAM RICHARDSON AND ROBT. THOMPSON.

Retiring Treasurer—B. G. NICHOL.

Retiring Councilmen—J. DARNEY, R. DOXFORD, G. B. HUNTER, J. PRICE, AND J. WEIR.

NOMINATIONS OF THE COUNCIL FROM WHICH TO SELECT NEW OFFICERS.

As President—W. BOYD.

As Vice-Presidents—A. COOTE, W. T. DOXFORD, C. MITCHELL, AND J. PRICE.

As Hon. Treasurer—B. G. NICHOL.

As Councilmen—J. AITCHISON, J. BROCKAT, A. E. LONG, W. G. SPENCE, J. C. STIRZAKER, R. THOMPSON, AND R. L. WEIGHTON.

Proposed by Mr. D. MYLES:—"That Mr. James Patterson be added to the list of nominations for councilmen."

Seconded by Mr. W. R. CUMMINGS.

Mr. Patterson's name was accordingly added to the list.

Mr. RUSSELL SINCLAIR then read a paper on "The Twisting Moments on Crank Shafts of Different Engines."

A discussion followed the reading of the paper.

The PRESIDENT proposed a vote of thanks to Mr. Sinclair for his paper, which was carried by acclamation.

The CHAIRMAN, in closing the meeting, congratulated the members upon the successful close of a successful session.

The Closing Business Meeting of the Institution for Session 1884–5 was held in the Lecture Hall of the Literary and Philosophical Society, Newcastle-on-Tyne, on Wednesday, May 13th, 1885, at 7·45 p.m.

W. BOYD, Esq., President, in the chair.

The ASSISTANT SECRETARY having read the minutes of the General Meeting on April 30th, they were approved by the meeting, and signed by the Secretary.

The PRESIDENT having appointed Messrs. Macoll and Stirzaker to examine the ballot for applications of membership made at the meeting, declared the following applicants, as submitted by the Council, had been elected :—

AS MEMBERS.

Bittleston, W. H., General Steam Navigation Co., Lombard Street, London.
Conning, A. C., Dunston Forge, Dunston.
Dykes, J., 107, Beaconsfield Street, Newcastle.
Davie, A. O., 15, Azalea Terrace, Sunderland.
Echmann, J., Sunderland Engine Works.
Elliott, Consitt, 4, Suffolk Street, Sunderland.
Hunter, J. W., 36, Blandford Street, Sunderland.
Johnson, J., 80, Dock Street, Sunderland.
Kirtley, J. T., 4, Ward Street, Sunderland.
Liddle, G., 99, Frederick Street, South Shields.
Robinson, W., 6, Choppington Street, Newcastle.
Sutherland, W., Sunderland.
Waugh, G. W., Monkseaton.

AS GRADUATES.

Annison, J. G., 52, Pilgrim Street, Sunderland.
Barrow, T. P., 27, Dock Street, Sunderland.
Bowman, R., 21, Dundas Street, Sunderland.
Brown, T., 12, Grace Terrace, Sunderland.
Brown, R., 114, Roker Avenue, Sunderland.
Carpenter, F., 22, De Grey Street, Newcastle.
Common, F., 13, Tavistock Place, Sunderland.
Crosby, J., 1, Randolph Street, Sunderland.
Davie, W. A., 15, Azalea Terrace, Sunderland.
Dickinson, F., Park House, Sunderland.
Fairbairn, J., 11, Horatio Street, Sunderland.
Gibbins, W., 17, St. Vincent Street, Sunderland.
Hamilton, G., 76, Dundas Street, Sunderland.
Harding, B., 9, Framlington Place, Newcastle.
Henshall, S., 24, Crowtree Road, Sunderland.
Horner, J., 22, Murton Street, Sunderland.
Kennedy, W. J., 107, Low Street, Sunderland.
Keene, H. R., 126, Park Road, Newcastle.
Laudreth, E., 26, Dock Street, Sunderland.
Maddison, G. D., 9, Salem Avenue, Sunderland.
Metcalf, T., Jun., 6, Dundas Street, Sunderland.
Milburn, J. W., 6, Azalea Terrace, Sunderland.
Milne, T., 41, Addison Street, Sunderland.
Muir, A. E., 96, Roker Avenue, Sunderland.
Nelson, H., 80, Dundas Street, Sunderland.
Newton, W. A., 7, Victoria Terrace, South Shields.
Ramshaw, G., 31, Barclay Street, Sunderland.
Scott, H., 47, Mainsforth Terrace, Sunderland.
Shiells, J., 22, Tunstall Vale, Sunderland.
Smiles, R., 10, Gibson Terrace, Sunderland
Spencer, P. G., 8, Victoria Street, Newcastle.
Stoddard, S., 24, Milburn Street, Sunderland.
Stafford, W., 28, High Street, Sunderland.
Thompson, F., 13, Chester Road, Sunderland.
Toomer, C. R., 26, North View, Heaton.
Watson, A. R., 6, Westbourne Road, Sunderland.
Wardle, W., 52, Harrogate Street, Sunderland.
Wheatley, J. J., 5, Garden Place, Sunderland.
Wiseman, H., 5, Dock Street, Sunderland.
Younger, C., 52, Victor Street, Sunderland.

The PRESIDENT then declared, as the result of the ballot for officers, that the following gentlemen had been elected to the vacant offices:—

New President—W. BOYD (re-elected).

New Vice-Presidents—C. MITCHELL AND J. PRICE.

New Treasurer—B. G. NICHOL (re-elected).

New Councilmen—J. BROCKAT, W. T. DOXFORD, W. G. SPENCE, ROBT. THOMPSON, AND R. L. WEIGHTON.

Proposed by Mr. MACOLL, "That Mr. R. W. Sisson, of the firm of Messrs. Sisson, accountants, carrying on business at County Chambers, Westgate Road, Newcastle, be appointed auditor to the Institution."

Seconded by Mr. W. HUTCHINSON.

Proposed by the PRESIDENT, "That the thanks of this Institution be awarded to Mr. W. G. Spence for his valuable services as Honorary Secretary to the Institution during the first year of its existence."

Seconded by Mr. B. G. NICHOL.

Carried unanimously.

The PRESIDENT said there was one subject in connection with papers to be read before the Institution to which he would wish to draw their attention, namely, the desirability of having papers on *practical* as well as on strictly *scientific* subjects. At the inaugural meeting of the session, Mr. W. Clark had alluded to this subject, and pointed out the desirability of having papers on matters of practical interest in the workshops in which they were daily engaged. He (the President) would like to emphasise that point. He believed there were among them many men, who were quite capable of writing valuable papers on practical subjects and matters of detail in connection with the every-day work of the shipyard or workshop, who might not feel themselves justified in attempting a paper of a highly scientific character. The one subject required a different training and a different cast of mind from the other. He had, in his Inaugural Address, alluded to a few points which were well worth the attention of members. The first was with reference to materials of construction. He was quite sure a very interesting paper could be read by some person connected with a shipyard, where vessels had been built both of iron and steel, showing the different peculiarities of each material, and the

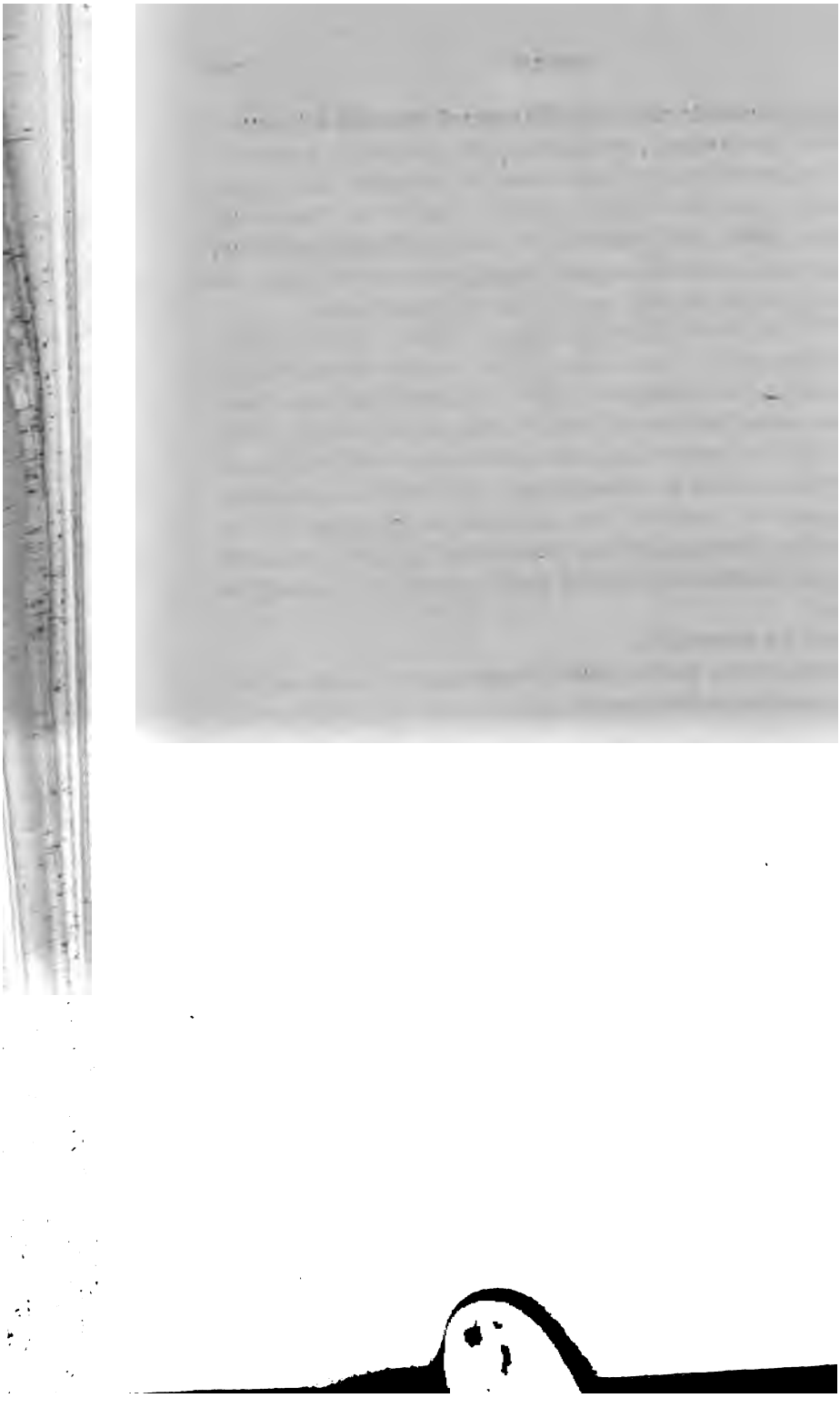
various experience in their use. The second was with reference to economy of production in the different yards, particularly in reference to the economy of transport or movement of material in the shipyard. He thought this was a subject on which they might have a very interesting paper and discussion. He would not further detain them on the subject, but would be glad if these ideas got spread among the members generally, so as to bear fruit in the coming session.

Mr. W. H. WHITE desired to propose a special vote of thanks to the President for his constant courtesy and his unwearied attention to the interests of the Institution. He could only say that if the Institution succeeded and grew strong and healthy, as he believed it would, it would owe very much of that success to the care which their President had bestowed on its earliest doings. It behoved them, therefore, to put upon the records of that Institution an expression of their thanks to the President for his conduct during that their first session.

Mr. H. MACOLL said he had great pleasure in seconding the resolution.

Carried by acclamation.

The PRESIDENT having thanked the members for re-electing him, declared the Session 1884–5 as closed.



LIST OF OFFICERS.

SESSION 1885-86.

President.

W. BOYD.

Vice-Presidents.

W. J. CLARK.
C. W. HUTCHINSON.
F. C. MARSHALL.
W. RICHARDSON.
R. THOMPSON.
W. H. WHITE.

Honorary Secretary.

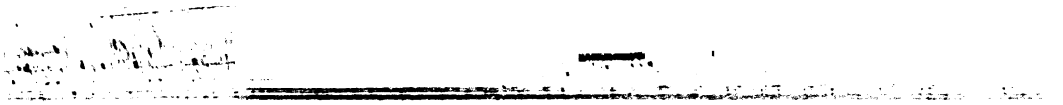
W. G. SPENCE.

Honorary Treasurer.

B. G. NICHOL.

Councilmen.

W. A. F. CRAWFORD.
J. DARNEY.
R. DOXFORD.
G. B. HUNTER.
J. H. IRWIN.
J. LAING, JUN.
H. MACOLL.
I. MAVOR.
A. R. MACKINTOSH.
J. PRICE.
R. SINCLAIR.
H. F. SWAN.
A. TAYLOR.
P. D. WINSTANLEY.
J. WEIR.



LIST

OF

Honorary Members, Members, Associates, and Graduates

OF THE

North-East Coast Institution of Engineers and Shipbuilders.

FIRST SESSION, 1884-5.

Honorary Members.

Sir W. G. Armstrong, C.B., LL.D., F.R.S., Jesmond Dene, Newcastle
The Right Honourable the Earl of Ravensworth

Members.

1 Aitchison, Jas., Hylton, Sunderland
2 Ahlbom, C., Messrs. R. & W. Hawthorn, St. Peter's, Newcastle
3 Alchin, A. N., 89, Wood Lane, Shepherd's Bush, London
4 Allardes, Wm., 62, Bollingbroke Street, Heaton, Newcastle
5 Allan, J. Thos., The Green, Wallsend, Newcastle
6 Allan, Wm., Northumberland Engine Works, Wallsend
7 Allison, Wm., 14, Nelson Street, Sunderland
8 Almond, H. J., Cannon Street Buildings, 139, Cannon Street, London
9 Anderson, A., Bright Street, Monkwearmouth, Sunderland
10 Anderson, J., Messrs. Wigham Richardson & Co., Walker, Newcastle
11 Andrews, Jas., 72, Bolingbroke Street, Heaton,
12 Appleby, W., 18, Race Street, Sandyford Road, Newcastle
13 Arnison, Geo., Jun., 5, Tavistock Place, Sunderland
14 Armstrong, A., Chester Street East, Millfield, Sunderland
15 Armstrong, G. S., 36, Suffolk Street, Sunderland
16 Austin, Stanley, Wear Dockyard, Sunderland
17 Austin, S. P., Wear Dockyard, Sunderland

18 Bailey, James, 8, Ashfield Terrace, Ryton-on-Tyne
19 Baird, Alex., 23, The Retreat, Sunderland
20 Bate, Edward R., 5, Ferndale Road, Clapham, London
21 Baxter, J., 56, Elsdon Road, Gosforth
22 Beadon, D. C., Messrs. R. and W. Hawthorn, St. Peters, Newcastle

23 Bearpark, John Charles, 7, Dock Street, Monkwearmouth, Sunderland
24 Bindisböll, J. S., Burdon Cottage, Jesmond
25 Bister, W., 4, Hume Street, Millfield, Sunderland
26 Bittleston, W. H., 5, Haddington Terrace, Greenwich, London, S.E.
27 Black, D. F., Elswick Shipyard
28 Black, Jas., Portobello Foundry, Sunderland
29 Black, Wm., Messrs. Black, Hawthorn, and Co., Gateshead
30 Bolton, Richard, 12, Rutland Street North, Pallion, Sunderland
31 Bone, W. J., 61, Linskill Terrace, North Shields
32 Bourn, John, 7, Byker Terrace, Walker
33 Boyd, Wm., 74, Jesmond Road, Newcastle
34 Brankston, R. T., 37, Hawthorn Street, Newcastle
35 Bremberg, G., 65, Croft Terrace, Jarrow
36 Brockat, John, 28, West Parade, Newcastle
37 Brown, N. K., 31, Grange Road West, Jarrow
38 Browne, B. C., 2, Granville Road, Jesmond, Newcastle
39 Buchanan, A., Messrs. Swan & Hunter, Wallsend
40 Buglass, A. W., 55, Milburn Terrace, Monkwearmouth, Sunderland
41 Burdon, J. G., 46, Lovaine Place, Newcastle
42 Burns, J., 31, Robinson Street, Sunderland
43 Bushell, C. A., 63, Quayside, Newcastle
44 Butterfield, George, 30, John Candlish Road, Millfield, Sunderland

45 Cairns, Hon. H., 79, Westmorland Road, Newcastle
46 Callis, Frank, South Hylton Vicarage, Sunderland
47 Cameron, H., 6, St. Vincent Street, Sunderland
48 Campbell, Hartley, Sunderland Engine Works, Sunderland
49 Carnegie, Alexander, 21, Westmorland Road, Newcastle
50 Carr, J. W., Point Pleasant House, Wallsend
51 Carrick, H., Holly House, Gateshead
52 Cay, Arthur, Westoe, South Shields
53 Charlton, T., 25, Lincoln Street, Gateshead
54 Charlton, Henry, Messrs. Hawks, Crawshay & Co., Gateshead
55 Charlton, R. B., Jun., Manors Railway Station Works, Newcastle
56 Christie, C. A., 4, Colbeck Terrace, Tynemouth
57 Christie, C. J. D., Neptune Engine Works, Low Walker
58 Christie, J. D., 39, Marine Terrace, Blyth
59 Clark, Wm. J., Southwick Engine Works, Sunderland
60 Clark, Geo., jun., Southwick Engine Works, Sunderland
61 Clarke, Jas., Elswick Marine Engine Works, Newcastle
62 Clarke, Thos., Elswick Marine Engine Works, Newcastle
63 Colling, John, Messrs. Lambert Bros. & Colling, Sunderland
64 Conradi, Carl, 28, Rosedale Terrace, Newcastle

65 Coote, Arthur, Messrs. Andrew Leslie & Co., Hebburn
66 Craig, G. B., Messrs. Craig, Taylor, & Co., Stockton-on-Tees
67 Crawford, W. A. F., Palmer's Hill Engine Works, Sunderland
68 Cruddas, W. D., Messrs. Armstrong, Mitchell, and Co., Elswick
69 Cummings, John, Low Fell, Gateshead
70 Cummins, W. R., Neptune Engine Works, Low Walker
71 Cutter, W., Armstrong, Mitchell, & Co., Elswick Works

72 Dale, Francis Allen, 25, Whickham Street, Monkwearmouth, Sunderland
73 Darney, John, Messrs. Short Bros., Sunderland
74 Davis, F. B., Wallsend
75 Davis, F. E., Wallsend
76 Davison, John, 7, Park Row, Southwick, Sunderland
77 Davy, Wm., 82, Georges Road, Elswick, Newcastle
78 Dempsey, L., Wallsend Slipway and Engineering Co., Wallsend
79 Derby, J. W., Messrs. J. & G. Thompson, Clyde Bank, Glasgow
80 Dickinson, John, Park House, Sunderland
81 Dickinson, James, Park House, Sunderland
82 Dickinson, W., Park House, Sunderland
83 Dixon, Frederick, Hebburn Villa, Hebburn
84 Dobson, Chr., Messrs. Dobson and Co., Low Walker
85 Dobason, T., The Teams, Gateshead
86 Dobason, W., The Teams, Gateshead
87 Donald, James, 12, Merle Terrace, Sunderland
88 Donovan, J. W., 4, Elizabeth Street, Newcastle Road, Sunderland
89 Down, S. B., 24, Georges Road, Elswick, Newcastle
90 Doxford, Charles D., Sashbrooke Terrace, Sunderland
91 Doxford, R. P., Pallion Engine Works, Sunderland
92 Doxford, W. T., Grinden Hall, Sunderland
93 Duckitt, Jno., Exchange Buildings, King Street, Newcastle
94 Dudgeon, F. S., Wallsend Slipway and Engineering Co., Wallsend
95 Duffield, Thomas, 2, Plantation Road, Pallion, Sunderland
96 Dykes, James, 107, Beaconsfield Street, Newcastle

97 Eckmann, John, Sunderland Engine Works, Sunderland
98 Edwards, G. S., Northumberland Shipyard, Howdon
99 Elliott, Consitt, 4, Suffolk Street, Sunderland
100 Engelbach, Herbert, Armstrong, Mitchell, & Co., Elswick Works
101 Evers, G., Germania Werft, Kiel, Germany

102 Farina, A. J., Oakwood House, Westmorland Road, Newcastle
103 Farquharson, R. Nesham, The Minories, Jesmond
104 Fitzgerald, J. F. G., 37, Rye Hill, Newcastle

105 Fleming, Charles Edward, 71, Elswick Road, Newcastle
106 Foley, Nelson, Messrs. R. & W. Hawthorn, St. Peter's
107 Foster, Henry, Newburn Steel Works, Newburn
108 Fownes, Henry, Tyne Forge Co., Limited, Ouseburn, Newcastle

109 Gad, Oscar, 4, Western Hill, Sunderland
110 Gannoway, J. G., Messrs. Armstrong, Mitchell, & Co., Low Walker
111 Gibbons, Chas. Kenrick, 27, Choppington Street, Newcastle
112 Gibson, H., 72, Roker Avenue, Sunderland
113 Gibson, W. H., 11, Booth Street, Sunderland
114 Glencross, Thos., 11, Rychill, Newcastle
115 Glover, Thomas, 34, Ellerslie Terrace, Sunderland
116 Graham, Edwin, Messrs. Osborne, Graham, & Co., Hylton, Sunderland
117 Graham, Joseph, South Hylton, Sunderland
118 Graham, Wm., Hylton, Sunderland
119 Grant, John Macpherson, 63, Westmorland Road, Newcastle
120 Gravell, John, Custom House Court, Quay, Newcastle
121 Gray, Harry, 12, Hawthorn Street, Newcastle
122 Grey, James, 14, Howick Place, Monkwearmouth
123 Green, W. G., Messrs. Palmer & Co., Jarrow
124 Greener, G. W., 110, Georges Road, Newcastle
125 Grenfell, Capt. H. H. Greystoke, Grainger Park Road, Newcastle
126 Greenwell, T. S., 21, Holly Terrace South, Sunderland
127 Grier, Jas., 85, Woodbine Street, South Shields
128 Gulston, A., 55, Holly Avenue, Jesmond, Newcastle

129 Hamilton, R. R., Rose Cottage, Willington
130 Hands, Geo., Sunderland Shipbuilding Co., South Dock, Sunderland
131 Hansen, F. T., Messrs. Black, Hawthorn, & Co., Gateshead
132 Harding, J. C., 14, Pilgrim Street, West Hartlepool
133 Harkness, Richard, Messrs. Palmer & Co., Jarrow
134 Hartness, J., East Boldon, near Sunderland
135 Harlow, F., 40, Clarence Crescent, Newcastle
136 Harper, J. H., 47, Grey Street, Tynemouth Road, North Shields
137 Harrald, Alexander, 19, Lawton Street, Newcastle
138 Haver, Arthur H., 15, Howarth Street South, Hylton Road, Sunderland
139 Hawkey, G., 3, King's Place, Millfield, Sunderland
140 Hebden, Sylvester, 77, Westmorland Road, Newcastle
141 Henderson, George, 54, Westmorland Road, Newcastle
142 Henderson, George, 5, Potts Street, Millfield, Sunderland
143 Henderson, G. B., 23, Holmside, Borough Road, Sunderland
144 Henderson, Robert, 11, Hadrian Road, Wallsend
145 Hepple, G. H., 19, Mount Pleasant, Deptford, Sunderland

146 Hildrey, A. J., 11, Chester Street, Sunderland
147 Hill, Maxwell, Messrs. Palmer & Co., Jarrow
148 Hindhaugh, C. W., 59, Bedford Street, North Shields
149 Hindson, William, 3, Claremont Park, Gateshead
150 Homji, A. C. N., 13, Trinity Street, Chobitalas, Bombay
151 Hope, Luke, 55, Milburn Terrace, Monkwearmouth, Sunderland
152 Howie, James, Central Marine Engineering Co., West Hartlepool
153 Hoyle, W. J., Bentinck Villas, Newcastle
154 Hunter, J. W., 36, Blandford Street, Sunderland
155 Hunter, George B., Messrs. Swan, Hunter, & Co., Wallsend
156 Hutchinson, C. W., Messrs. Armstrong, Mitchell, & Co., Elswick Works
157 Huxham, J. L., 7, St. George's Terrace, Sunderland

158 Irwin, J. H., Sunderland Engine Works, Sunderland

159 Jackson, F., 26, York Street, Newcastle
160 James, M. C., Messrs. Schlesinger, Davis, & Co., Wallsend
161 Jobling, J. C., 25, St. Thomas' Street, Newcastle
162 Jobling, W. J., Lombard Street, Newcastle
163 Johnson, T. Allen, 52, Harrison Street, Barrow-in-Furness
164 Johnson, R., 4, Olive Street, Sunderland
165 Johnson, William, 10, Aubrey Terrace, Sunderland
166 Johnson, John, 80, Dock Street East, Sunderland

167 Kean, James, 3, Croft Terrace, Jarrow
168 Key, Alexander, Mersey Chambers, Liverpool
169 Kilvington, W., Northumberland Engine Works, Wallsend
170 Kirtley, J. T., 4, Ward Street, Sunderland

171 Laing, Arthur, Deptford Yard, Sunderland
172 Laing, Jas., jun., Deptford Yard, Sunderland
173 Laing, John, Messrs. R. & W. Hawthorn, St. Peter's
174 Landreth, J., 54, Warwick Street, Monkwearmouth
175 Larkin, James, East Jarrow
176 Lax, G. W. A., 21, Ann Street, Sunderland
177 Leggatt, C. E., Kepple House, South Shields
178 Lewis, R. A., Newburn Steel Works, Newburn
179 Liddell, A. R., 51, Harrison Street, Barrow-in-Furness
180 Liddell, J., 10, St. Vincent Street, Sunderland
181 Lindsay, J. C., 5, Park Place West, Sunderland
182 Livingstone, John, 25, Grove Street, Newcastle
183 Livingston, Thos., St. John's Terrace, Jarrow
184 Lohmeyer, H., 29, Choppington Street, Elswick

185 Long, A. E., 124, Albert Road, Jarrow
186 Lynn, J., St. Luke's Engine Works, Sunderland

187 Mackenzie, W. S., 76, De Grey Street, Newcastle
188 Mackintosh, A. E., Tynemouth
189 Maclean, A. J., 8, Lawton Street, Newcastle
190 Macoll, D. C., 45, Dock Street, Monkwearmouth, Sunderland
191* Macoll, H., Wear Dockyard, Sunderland
192 Magill, David, The Green, Wallsend
193 Marlborough, Richard, 12, Smyrna Place, Sunderland
194 Marr, James, 6, Ash Place, Sunderland
195 Marshall, F. C., Messrs. R. & W. Hawthorn, St. Peter's
196 Matthews, A., The Baths, Blyth
197 Mavor, Ivan, Messrs. Armstrong, Mitchell, & Co., Low Walker
198 McDonall, H. B., 118, Park Road, Newcastle
199 McIntyre, John, 8, Abbotsford Terrace, Newcastle
200 McIlvenna, J. G., High Docks House, South Shields
201 McKay, Jno., Messrs. R. & W. Hawthorn, St. Peter's
202 Menzies, Wm., The Side, Newcastle
203 Metcalf, J. C., Messrs. Culliford & Clark, Sunniside West, Sunderland
204 Metcalf, C. S., 38, Frederick Street, Sunderland
205 Millar, Thos., 81, Grange Road West, Jarrow
206 Milne, W. J., Northumberland Shipyard, Howdon
207 Mitchell, Chas., Jesmond Towers, Newcastle
208 Moffat, D., 36, Falconar Street, Newcastle
209 Morgan, C. E., Messrs. Wigham Richardson & Co., Low Walker
210 Morgan, W. H., Messrs. R. & W. Hawthorn, St. Peter's
211 Mörk, Paul, 3, Hawthorn Street, Newcastle
212 Morison, D. B., Messrs. T. Richardson & Sons, Hartlepool
213 Morrison, Jas., 61, Gloucester Road, Newcastle
214 Morrison, Joseph, 39, St. Cuthbert Terrace, Sunderland
215 Mowat, John, 18, Howarth Street, Sunderland
216 Muir, J. M., Messrs. Wigham Richardson & Co., Low Walker
217 Myles, David, Neptune Engine Works, Low Walker

218 Napier, W. E., 23, Grange Road, Jarrow
219 Nichol, B. G., Messrs. Donkin & Nichol, Newcastle
220 Nichol, J., Linskill Place, North Shields
221 Nichol, Thos., 50, Ripon Street, Monkwearmouth, Sunderland
222 Nicholson, J. T., 219, Norfolk Road, Heaton
223 Nicholson, W. E., Oakfield, Ryton
224 Nicolaus, Julius, Kirby-in-Furness
225 Norman, W. S., River Tyne Boiler Works, Low Walker
226 Noton, F. R., 32, Azalea Terrace, Sunderland

* Life Member.

227 O'Neil, J. J., 23, Howard Street, Sunderland
228 Oxley, G., Station Road, Howdon

229 Parkin, Rd., Messrs. Donkin & Nichol, Gallowgate, Newcastle
230 Paton, W. E., Vaalafiel, 94, Edith Road, West Kensington, London, S.W.
231 Patterson, Jas., 19, Hawthorn Street, Newcastle
232 Pattison, Jos., 2, Church Terrace, Wallsend
233 Pearce, C. W., 13, Nesham Street, Newcastle
234 Penny, A. W., 69, Percy Road, Whitley
235 Penny, W. H., 15, Azalea Terrace South, Sunderland
236 Phillipson, M., 12, Dame Dorothy Street, Sunderland
237 Phillipson, R., Tynemouth
238 Phorson, P., 82, Roker Avenue, Sunderland
239 Pickering, Thos., 126, Herrington Street, Sunderland
240 Pilling, J., Southwick Engine Works, Sunderland
241 Plews, G. W., Elswick Ordnance Works, Elswick
242 Popper, S., 8, Hawthorn Street, Newcastle
243 Potts, A. W., 15, St. Bede's Terrace, Sunderland
244 Potts, Cuthbert, 1, Gibson Terrace, Chester Road, Sunderland
245 Potts, John George, 8, Gladstone Street, Sunderland
246 Price, John, Messrs. Palmer & Co., Jarrow
247 Prince, Alfred, Kent Villa, Jarrow
248 Purdy, A. J., Willington Quay, Newcastle
249 Putnam, T., Darlington Forge, Darlington
250 Putnam, William, Darlington Forge, Darlington

251 Ramsay, C., 25, Leazes Terrace, Newcastle
252 Rankine, Jno., 21, Payne Street, North Shields
253 Readhead, R., Sea View, South Shields
254 Readhead, Jas., Argyle Terrace, South Shields
255 Reed, J. W., 49, Croft Terrace, Jarrow
256 Ridley, J. C., 3, Summerhill Grove, Newcastle
257 Ridley, J. H., Messrs. R. & W. Hawthorn, St. Peter's
258 Richardson, W., 31, Bolingbroke Street, Heaton
259 Richardson, Wigham, Neptune Engine Works, Low Walker
260 Ripley, P. E., Messrs. Ransome's, Sims, & Jefferies, Ipswich
261 Ritson, M., 3, Mowbray Terrace, Sunderland.
262 Robinson, B. A., 6, Argyle Street, Sunderland
263 Robson, M., 4, Dock Street, Monkwearmouth, Sunderland
264 Robson, J. M., care of W. Whyte, B, Lombard Street, Newcastle
265 Ross, J. A. G., 46, Grainger Street West, Newcastle
266 Rowe, J. A., 11, Spring Terrace, North Shields
267 Rowell, G. W., 22, Durham Street, Newcastle
268 Rowell, H., Jesmond Gardens, Newcastle

269 Rusden, L., 11, Mistletoe Road, Jesmond, Newcastle
270 Rutter, Th., 47, St. Mark's Road, Sunderland
271 Rutherford, T. A., 52, Harrison Street, Barrow-in-Furness

272 Salmon, P., 14, Azalea Terrace North, Sunderland
273 Sanderson, J., 31, Park Road, Jarrow
274 Sandison, M., 34, Park Road, Newcastle
275 Schaeffer, A. G., 38, Eldon Street, Newcastle
276 Scott, Ernest, Close, Newcastle
277 Scott, Wm., Messrs. R. & W. Hawthorn, St. Peter's
278 Scorer, G. S., Messrs. T. & W. Smith, North Shields
279 Scotson, Wm., Lemington Hall
280 Shand, H., 8, Ridley Villas, Newcastle
281 Sharp, A. E., Albert Terrace, Jarrow
282 Sharpe, W. L., 9, Tunstall Terrace, Sunderland
283 Shaw, Jas., 24, Blyth Terrace, Gateshead
284 Shaw, W. B., 49, Ryehill Newcastle
285 Sheppard, W. O., Messrs. Shearer's, Pottery Lane, Newcastle
286 Shevill, W. H. S., Avenue Terrace, Sunderland
287 Short, J. Y., 49, West Sunniside, Sunderland
288 Short, Jos., 49, West Sunniside, Sunderland
289 Simey, G. H. F., 6, St. Bede's Terrace, Sunderland
290 Sinclair. R., Wallsend Slipway and Engineering Co., Wallsend
291 Sisterson, G. R., 247, Hamilton Street, Newcastle
292 Sjögren, H., 21, Lawton Street, Newcastle
293 Smith, Eustace, 5, Queen Street, Newcastle
294 Smith, J., 3, St. Cuthbert's Terrace, Sunderland
295 Smith, R. J., 2, West Lawn, Sunderland
296 Smith, Wm., 51, Dock Street East, Sunderland
297 Smith, Thomas Edward, Messrs. John Smith & Sons, Newgate Street, Newcastle
298 Soliani, Nabor, 8, Victoria Square, Newcastle
299 Spence, Jas. C., Akenside Hill, Newcastle
300 Spence, W. G., 66, Elswick Road, Newcastle
301 Spencer, R. E. E., 4, Malvern Street, Newcastle
302 Spencer, J. W., Newburn Steel Works, Newburn
303 Spiers, James, 5, Grange Crescent, Southwick, Sunderland
304 Stephenson, C., 42, West Street, Wallsend
305 Stevenson, Wm., Messrs. R. & W. Hawthorn, St. Peter's
306 Stirzaker, J. C., St. Mary's Terrace, Ryton
307 Stone, Wm., 13, Rosslyn Terrace, Sunderland
308 Stuart, G. W., 72, Coronation Street, Sunderland
309 Stubbings, Jas., Cornhill, Sunderland
310 Surtees, R., Messrs. R. & W. Hawthorn, St. Peter's

311 Surtees, W. H., 38, 9, and 40, Sans Street, Sunderland
312 Sutton, James, 68, Park Road, Newcastle
313 Swan, H. F., Messrs. Armstrong, Mitchell, & Co., Low Walker
314 Swan, Thomas, 152, Ellison Street, Jarrow
315 Swainston, Wm., Rokeby Street, St. Mary's Road, Sunderland
316 Swinburne, M. W., Messrs. H.Watson & Sons, High Bridge, Newcastle
317 Swinburne, T. M., Bewick Road, Gateshead
318 Swinton, A. A. Campbell, Messrs. Armstrong, Mitchell, & Co., Elswick
319 Symington, H. J. W., 1, Linden Terrace, Newcastle

320 Tate, Chas. H., 7, Side, Newcastle.
321 Taylor, C. W., Dene Crescent, Walker
322 Taylor, Aldexander, 22, Waverley Terrace, Newcastle
323 Taylor, J. E., 5, Bellevue Road, Sunderland
324 Thompson, C. E., Southwick Yard, Sunderland
325 Thompson, J. E., Thornhill Park, Sunderland
326 Thompson, J. L., Jun., North Sands, Sunderland
327 Thompson, Nicol, 62, Grove Street, Newcastle
328 Thompson, Robert, North Sands, Sunderland
329 Thompson, R. C., Messrs. Thompson & Sons, Southwick, Sunderland
330 Thompson, John, Post Office Chambers, Newcastle
331 Thorn, W. H., 5, Waterville Terrace, North Shields
332 Todd, Surtees, Messrs. A. Leslie & Co., Hebburn
333 Trewent, F. J., Messrs. Swan & Hunter, Wallsend
334 Tritton, S. B., 42, Leazes Terrace, Newcastle
335 Turnbull, T. W. H., 17, Monk Street, Monkwearmouth, Sunderland
336 Tweedy, J., Neptune Engine Works, Low Walker
337 Tweddell, R. H., 14, Delahay Street, Westminster, London, S.W.

338 Ullstrom, Otto, 65, Croft Terrace, Jarrow

339 Vercoe, Jas., 3, Aubrey Place, Sunderland

340 Wailes, E. F., 8, Lombard Street, Newcastle
341 Walker, G., Messrs. Armstrong, Mitchell, & Co., Elswick
342 Wallau, J., Messrs. Black, Hawthorn, & Co., Gateshead
343 Walton, J. G., Esplanade West, Sunderland
344 Warburton, J., 16, Elmwood Street, Sunderland
345 Warren, Wm., 29, Warwick Street, Sunderland
346 Watt, Adam, 6, Alice Street, Sunderland
347 Waugh, G. W., Monkseaton
348 Webster, R. S., Dene Cottage, Walker-on-Tyne
349 Wedgwood, A. D., Guildhall Chambers, Quay, Newcastle
350 Weighton, R. L., Messrs. R. & W. Hawthorn, St. Peter's
351 Weir, John, Messrs. Ramage & Ferguson, Leith

352 Welch, W. E., 42, Percy Road, Whitley
353 Westmacott, P. G. B., Elswick Works
354 Wharrier, J., Byker Terrace, Walker
355 White, C., 13, Mosley Street, Newcastle
356 White, R. S., Messrs. Armstrong, Mitchell, & Co., Low Walker
357 White, W. H., Messrs. Armstrong, Mitchell, & Co., Elswick
358 Whyte, Wm., Lombard Street, Newcastle
359 Widdas, T. D., 13, Peet Street, Gladstone Road, Liverpool
360 Wilkie, J., 2, Gilsland Street South, Sunderland
361 Willcox, F. W., 45, Sunniside West, Sunderland
362 Williams, J., 3, Azalea Terrace, Sunderland
363 Williams, T. R., 120, Albert Terrace, Jarrow
364 Willis, Jos. 78, Gosforth Street, Monkwearmouth, Sunderland
365 Winstanley, P. D., Messrs. Armstrong, Mitchell, & Co., Elswick
366 Wilson, O., 4, Pallion Road, Bishopwearmouth, Sunderland
367 Wilson, T. N., Monk Street Engine Works, Sunderland
368 Wilson, T., Wallsend Slipway and Engineering Co., Wallsend
369 Withy, H. Middleton, Shipyard, West Hartlepool
370 Wright, R., 25, Westmorland Road, Newcastle
371 Wyllie, R., Messrs. Richardson & Sons, Hartlepool
372 Young, M. C., 19, Havelock Street, Newcastle
373 Younger, R., Messrs. R. & W. Hawthorn, St. Peter's
374 Zeltz, A., 48, Harrison Street, Barrow-in-Furness
375 Zimmermann, R., Germania Werft, Kiel, Germany

Associates.

1 Barwick, J. S., Ashbrook Grange, Sunderland
2 Beckingham, J. H., Messrs. Scott Brothers, Quayside, Newcastle
3 Bell, C. R., 22, Osborne Avenue, Newcastle
4 Bell, M. H., 20, John Candlish Road, Millfield, Sunderland
5 Boyd, Robert, Messrs. Hannay, Boyd, and Co., Quay, Newcastle
6 Culliford, J. H. W., Sunderland
7 Dunford, T. G., Messrs. Elliott, Lowrey, and Dunford, Quay, Newcastle
8 Fisher, Jos., Messrs. Fisher, Renwick, and Co., Quay, Newcastle
9 Gill, Harry, 13, Mosley Street, Newcastle
10 Gracie, J. L., 53, Percy Park, Tynemouth
11 Green, F. W., 14, Monk Street, Monkwearmouth

12 Hollis, H. E., 16, Stanwick Street, Tynemouth
13 Hutchinson, G., 1, St. Nicholas' Buildings, Newcastle

14 Laws, G. A., Messrs. Laws, Surtees, & Co., Quayside, Newcastle
15 Lowrey, E., Messrs. Elliott, Lowrey, & Dunford, Quayside, Newcastle

16 Miller, T. R., Maritime Buildings, King Street, Newcastle
17 Mudd, Wm., Castletown Rolling Mills, near Sunderland
18 Mulherion, G. F., 247, Albert Road, Jarrow

19 Newby, S., Messrs. Thomson & Newby, 13, Bridge Street, Sunderland
20 Nixon, John, Blyth Shipbuilding Co., Blyth

21 Osbourne, Jas., Hylton, Sunderland

22 Panton, H., 38, Side, Newcastle
23 Patterson, J., Wincomblee, Low Walker
24 Patterson, Thos., Hylton, Sunderland

25 Ramsay, J. W., Newburn Steel Works, Newburn
26 Reah, J. H., Lombard Street, Newcastle
27 Reichwald, A., Lombard Street, Newcastle
28 Reid, Andrew, Akenside Hill, Newcastle
29 Renwick, G., Messrs. Fisher, Renwick, & Co., Quay, Newcastle
30 Ritson, F., 18, St. Bede's Terrace, Sunderland
31 Roberts, G., Baltic Chambers, Newcastle
32 Robson, Thos., 28, North Bridge Street, Sunderland
33 Roche, W. M., 2, Thornhill Gardens, Sunderland

34 Scholefield, A., 1, St. Nicholas' Buildings, Newcastle
35 Scott, W. H., Messrs. Scott Brothers, Queen Street, Newcastle
36 Snowball, T., Crown Buildings, Side, Newcastle
37 Stephens, D., Messrs. Stephens, Mawson, & Co., Quay, Newcastle

38 Wait, James, Maritime Buildings, Quay, Newcastle

Graduates.

1 Andlaw, W. F., 13, Russell Street, North Shields

2 Barley, C. J., 26, North View, Heaton
3 Barrow, T. P., 27, Dock Street, Sunderland
4 Brown, T. R., 12, Grace Terrace, Sunderland

5 Carpenter, F., 22, De Grey Street, Newcastle
6 Common, F., 13, Tavistock Place, Sunderland

7 Cornish, H. P., 47, Fisher Street, Low Walker
8 Crosby, J., 1, Randolph Street, Sunderland

9 Dickinson, F., Park House, Sunderland

10 Fairbairn, Jas., 11, Horatio Street, Sunderland
11 Fisher, John, 1, Vicarage Terrace, Sunderland

12 Garrett, H. A., 15, Belgrave Terrace, Newcastle
13 Gibbins, W. M., 17, St. Vincent Street, Sunderland
14 Grieves, R. 38, Linskill Terrace, North Shields

15 Harding, B. J., 9, Framlington Place, Newcastle
16 Head, A. P., 23, North View, Heaton
17 Henshall, Samuel, 24, Crow Tree Road, Sunderland

18 Keene, H. Ruck, 126, Park Road, Sunderland

19 Landreth, E., 26, Dock Street East, Sunderland

20 Maddison, G. D., 9, Salem Avenue, Sunderland
21 Marshall, F. T., 38, Percy Gardens, Tynemouth
22 Metcalf, Thos., 6, Dundas Street, Sunderland
23 Muir, A. E., 96, Roker Avenue East, Sunderland

24 Nelson, Henry, 80, Dundas Street, Sunderland
25 Newton, W. A., 17, Victoria Terrace, South Shields
26 Ramshaw, G. H., 31, Barclay Street, Sunderland
27 Reavell, Wm., Eslington North House, Jesmond, Newcastle
28 Robinson, Wm., 6, Choppington Street, Newcastle

29 Scott, H., 47, Mainsforth Terrace, Sunderland
30 Shiells, James, 22, Tunstall Vale, Sunderland
31 Spencer, P. G., 8, Victoria Street, Newcastle
32 Stoddart, Swinton, 24, North Milburn Street, Sunderland

33 Thompson, F., 13, Chester Road, Sunderland
34 Tone, J. M. F., 50, Clayton Park Square, Newcastle
35 Toomer, C. R., 22, North View, Heaton, Newcastle
36 Trist, P., 28, Hawthorn Street, Newcastle

37 Wardle, Wm., 52, Harrogate Street, Sunderland
38 Watson, A. R., 6, Westbourne Road, Sunderland
39 Wilson, J. T., 125, Walker Road, Newcastle